INTERREG VA IMPACT EVALUATION

PRIORITY 1 – RESEARCH AND INNOVATION - FINAL

Special EU Programmes Body
Foras Um Chláir Speisialta An AE
Boord O Owre Ocht UE Projecks

Cogent MANAGEMENT CONSULTING

Cogent Management Consulting LLP

6th October 2019

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PRIORITY 1 – RESEARCH AND INNOVATION

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APPENDICES

List of Abbreviations

Abbreviation	Definition
AAL	Ambient Assisted Living
AB	Advisory Board
ACS	Acute Coronary Syndrome
AD	Alzheimer’s disease
AD	Anaerobic Digestion
AFC	Authentic Food Company
AFRC	Advanced Forming Research Centre
AKI	Acute kidney injury
APC	Article Processing Charge
ARCH	Applied Research for Connected Health Centre
BDI	Biomedical Diagnostics Institute
BETTA	British Electricity Trading Transmission Arrangements
BERD	Business Expenditure of Research and Development
BIM	Business Integration Manager
BIM	Building Information Modelling
BREATH	Border and Regions Airways Training Hub
BSR	Business Status Review
C-Is	Catalyst Inc’s
c-Si	First Generation
C-TRIC	Clinical Translational Research and Innovation Centre
CAES	Compressed Air Energy Storage
CALIN	Celtic Advanced Life Science Innovation Network
CASALA	Centre for Affective Solutions for Ambient Living Awareness
CATS	Cambridge Academy of Therapeutic Sciences
CB	Cross Border
CEO	Chief Executive Officer
CE-SEA	Community Energy from Solar Envelope Architecture
CF	Clinical Fellow
CHF	Congestive Heart Failure
CI	Co-Investigators
CL	Commercial Lead
CO	Output Indicators
Co2	Carbon dioxide
Co-Innovate	The Innovation Pathway Programme
COPD	Chronic Obstructive Pulmonary Disease
CPM	Centre for Personalised Medicine: Clinical Decision Making and Patient Safety
CR	Cardiac Rehabilitation
CRP	Inflammatory Factors
CSRI	Computer Science Research Institute
CTE	Critical Technology Elements
CURAM	Centre for Research for Medical Devices
CVD	Cardiovascular Disease
DCNI	Director of Digital Catapult
DCSDC	Derry City and Strabane District Council
DCU	Dublin City University
DEL	Department for Employment and Learning, Northern
DIT	Department for International Trade
DJEI	Department of Jobs, Enterprise and Innovation
DKIT	Dundalk Institute of Technology
DME	Dimethyl ether
DNDI	Dementia and Neurodegeneration Ireland
DNO	Distribution Network Operator
DOFE	Design of Experiments
DSO	Distribution System Operators
DVEM	Dundalk Virtual Energy Microgrid
EAC	External Advisory Committee

Abbreviation	Definition
EBR	East Border Region Ltd
ECG	Electrocardiogram
ECME	Eastern Corridor - Medical Engineering Centre
EOI	Expressions of Interest
EOL	End-Of-Life
EP	Enterprise Partners
EQIA	Equality Impact Assessments
ER	Eligible Region
ERDF	European Regional Development Fund
ESB	Electricity Supply Board
ESCO	Energy Service Companies
ESG	Evaluation Steering Group
ESIF	European Structural and Investment Funds
EV	Electric Vehicles
FTEs	Full-Time equivalent employees
GBD	Global Burden of Disease
GBER	General block exemption Regulation
GD	Glen Dimplex
GENSSIS	Gravitational potential Energy Storage & Synchronous Inertial Stability
GHGs	Green House Gases
GIS	Geographic Information Systems
GDP	Gross Domestic Product
GNP	Gross National Product
GVA	Gross Value Added
HDOs	Healthcare Delivery Organisations
HEFCE	Higher Education Funding Council for England
HEFCW	The Higher Education Funding Council for Wales
HEV	Hybrid Electric Vehicles
HF	Heart Failure
HGSG	Human Genomics Strategy Group
HIE	Highlands and Islands Enterprise
HIPAA	Health Insurance Portability and Accountability Act
HLS	Health and Life Sciences
HP	Health Partners
HVMC	High-Value Manufacturing Catapult
IBD	Inflammatory Bowel Disease
ICA	Innovation Capability Audit
IDTs	Industrial Digitalisation Technologies
IIE	Institute of Industrial Engineers
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
IRR	Innovation Ready Reckoner
ISCE	The International Society for Computerized Electrocardiology
ISEM	Integrated Single Electricity Market
ITS	Institute of Technology Sligo
ITT	Invitations to Tender
KTN	Knowledge Transfer Network
L&HS	Life and Health Sciences
LEA	Local Enterprise Agency
LEO	Local Enterprise Offices
LoO	Letter of Offer
LPE	Laser Prototypes Europe
LPWANS	Low powered wide area networks
LTCs	Long Term Conditions
LUH	Letterkenny University Hospital
LyIT	Letterkenny Institute of Technology
MB	Management Board

Abbreviation	Definition
MDMs	Medical Device Manufacturers
MDO	Multi-Disciplinary Optimisation
MES	Mass Energy Storage
MI	Myocardial Infarction
MNI	Manufacturing NI
MRE	Marine Renewable Energy
NHSH	NHS Highlands
NI	Northern Ireland
NIBEC	Nanotechnology and Integrated Bio-Engineering Centre
NICRS	Northern Ireland Clinical Research Services
NIGEAE	Northern Ireland Guide to Expenditure Appraisal and Evaluation
NIUR	NI Utility Regulator
NREAP	National Renewable Energy Action Plan
NUIG	National Universities of Ireland Galway
NWCAM	North West Centre for Advanced Manufacturing
O&M	Operation and Maintenance
OA	Open Access
OECD	Organisation for Economic Co-operation and Development
ORECNI	Office of Research Northern Ireland
PAM	Passive Acoustic Monitoring
PC	Project Coordinator
PCI	Primary coronary intervention
PCI	Project of Common Interest
PCK9	Proprotein Convertase Subtilisin Kexin Type 9
PCM	Phase Change Materials
PDRA	Post-Doctoral Research Associate
PDRF	Post-Doctoral Research Fellows
PDT	Programme Delivery Team
PEEK	Polyether ether ketone
PfG	Programme for Government
PhD	Postgraduate Doctoral Degree
PI	Principal Investigator
PMB	Project Management Board
PMC	Project Management Committee
PNAS	Proceedings of the National Academy of Science
POC	Point of Care
POCT	Point-of-care testing
PP	Polypropylene
PRPA	Peer Review Paper Assessment Panel
PV	Photovoltaic
QUB	Queen’s University Belfast
R&D	Research & Development
R&D&I	Research, Development & Innovation
R&I	Research & Innovation
R&I	Research and Impact
RA	Research Associates
Randox	Randox Laboratories Ltd
RCs	Research Clusters
RE	Renewable Energy
REF	Research Excellence Framework
RF	Research Fellow
ROI	Republic of Ireland
ROS	Reactive Oxygen Species
RTDI	Research, Technology Development and Innovation
RY	Researcher years
SALMS	Sustainable Agricultural Land Management Strategy
SEF	Strategic Energy Framework
SEM	Single Electricity Market

Abbreviation	Definition
SEUPB	Special European Union Programmes Body
SFC	Scottish Funding Council
SMART	Specific, Measurable, Achievable, Realistic and Timebound
SMEs	Small and Medium-sized Enterprises
SMRC	Smooth Muscle Research Centre
SNEPs	Spontaneously Differentiated Neuroectodermal Progenitor Cell
SNSP	System Non-Synchronous Penetration
SOFC	Solid Oxide Fuel Cells
SONI	System Operator NI
SPIRE 1	Storage Platform for the Integration of Renewable Energy (2013-2015)
SPIRE 2	Storage Platform for the Integration of Renewable Energy
SSB	Scientific Supervisory Board
ST	Southern Trust
STEM	Science, Technology, Engineering and Maths
STEMM	Science, Technology, Engineering, Maths and Medicine
STLCA	Spatial-Temporal LCA
SWAN	Scientific Women's Academic Network
SWC	South West College
TCM	Thermochemical Materials
TE	Training Events
TES	Thermal Energy Storage
T-MED	Translational Medicine
TnI	Troponin I
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TSO	Transmission System Operators
TTM	Technology Transfer Manager
TTO	Technology Transfer Offices
UCD	University College Dublin
UFU	Ulster Farmer Union
UG	University of Glasgow
UHI	University of Highlands and Islands
UIR	Ulster Institutional Repository
UK	United Kingdom
UKRI	UK Research and Innovation
UoA	Unit of Assessment
US	University of Strathclyde
UU	Ulster University
UWS	University of the West of Scotland
VPH	Virtual Physiological Human
VRE	Variable Renewable Energy
VRGS	Virtual Research Graduate School
WEC	Wave Energy Converters
WHO	World Health Organisation
WHSCT	Western Health and Social Care Trust

Description of Statistics

In this report, proportions may be described as percentages, common fractions and in more general quantitative terms. Where more general terms are used, they should be interpreted as follows:

Almost/nearly all	more than 90%
Most	75%-90%
A majority	50%-74%
A significant minority	30%-49%
A minority	10%-29%
Very few/a small number	less than 10%

1. INTRODUCTION AND BACKGROUND

1.1 Introduction

The Special EU Programmes Body (SEUPB) has commissioned Cogent Management Consulting LLP (Cogent) to carry out an impact evaluation of INTERREG VA Programme[1] Investment Priority 1: Research and Innovation.

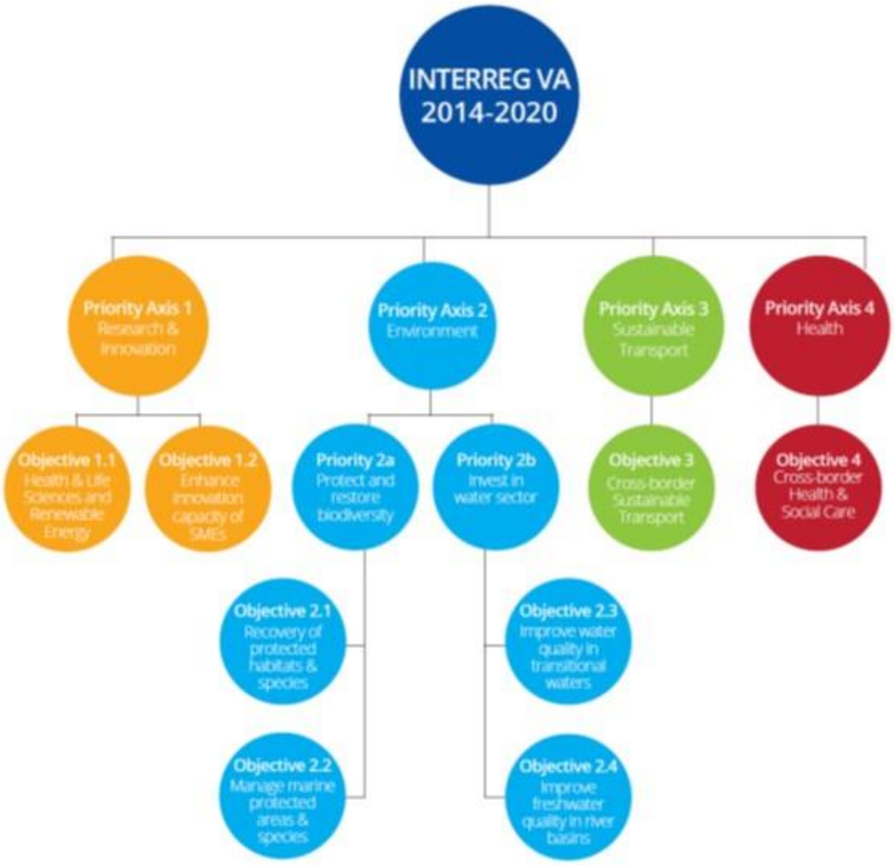
1.2 Background to the INTERREG VA Programme

Launched in January 2016, the INTERREG VA Programme is one of over 60 funding programmes across the EU that have been specifically designed to address problems that arise from the existence of borders. Borders can reduce economic development, hamper the efficient management of the environment, obstruct travel and hinder the delivery of essential health and social care services. The INTERREG VA Programme, therefore, aims to promote greater levels of economic, social and territorial cohesion to create a more prosperous and sustainable cross-border region.

The INTERREG VA Programme has a total value of €283m, which is funded as follows:

- 85% (€240m) via the European Regional Development Fund (ERDF), which is within the European Structural and Investment Funds (ESIF).
- 15% (€43m) via match funding from non-EU sources e.g. national, regional, local government, a project's own resources or private contributions. Contributions in-kind may be used as match-funding. NB: arrangements for match-funding may vary between priority axes of the Programme.

Figure 1.1: INTERREG VA Programme Priority Axes[2]



[1] For Northern Ireland, Ireland and Western Scotland
[2] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).

As depicted above, the INTERREG VA Programme has four key priority axes, which were selected to address identified weaknesses in the programme region's economy, as set out in the Cooperation Programme for the INTERREG VA Programme 2014-2020[3]. The Cooperation Programme states that the priority axes are congruent with 'Europe 2020 - A Strategy for Smart, Sustainable and Inclusive Growth' and the priority areas identified for European Territorial Cooperation within the EU Commission Position Papers for the UK and Ireland.

The following subsections provide further details of Priority Axis 1: Research and Innovation.

1.3 Priority Axis 1: Research and Innovation and its Objectives

1.3.1 Introduction

The Cooperation Programme states that the key aim of Priority Axis 1: Research and Innovation is to *"encourage investment in sectors that offer the most growth potential, whilst building on existing strengths, and helping the region to become more competitive in a global marketplace."*

It is anticipated that this priority axis will tackle two key weaknesses in the programme region's competitiveness, namely the:

1. The low levels of expenditure on research, development and innovation (R&D&I); and
2. An under-representation of higher value-added sectors and innovation-active small and medium-sized enterprises (SMEs)[4].

The **selected investment priorities** under Priority Axis 1: Research and Innovation and their **associated objectives** are as follows:

Table 1.1: Priority Axis 1 Investment Priorities and Specific Objectives

Investment Priority	Associated Specific Objectives	
1a - Enhancing research and innovation (R&I) infrastructure and capacities to develop R&I excellence, and promoting centres of competence, in particular, those of European interest.	**1.1**	Increasing business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences and Renewable Energy.
1b - Promoting business investment in R&I, developing links and synergies between enterprises, R&D centres and the higher education sector, in particular promoting investment in product and service development, technology transfer, social innovation, eco-innovation, public service applications, demand stimulation, networking, clusters and open innovation through smart specialisation, and supporting technological and applied research, pilot lines, early product validation actions, advanced manufacturing capabilities and first production, in particular in key enabling technologies and diffusion of general-purpose technologies.	**1.2**	Increasing the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services.

[3] Formally adopted in February 2015.
[4] The Output Indicator Guidance document for Objective 1.2 (February 2016) defines SMEs as having: fewer than 250 full-time equivalent employees (FTEs), an annual turnover not exceeding €50m and/or an annual balance sheet total not exceeding €43m. Sole traders are excluded from this definition to maintain the purpose and ambitions of the INTERREG VA Programme to achieve significant change.

1.3.2 *Objective 1.1 - Increasing business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences and Renewable Energy*

The Co-operation Programme notes that the eligible region's economies are characterised by a low proportion of high value-added, exporting sectors and low levels of R&I. Noting that Research, Development and Innovation (R&D&I) is a key mechanism for the eligible region to realise its shared policy agenda to transform the region into a knowledge-based economy, characterised by increased research capacity and capability, which can produce new intellectual property, human capital and attract foreign direct investment, it is anticipated that the INTERREG VA Programme presents an opportunity to encourage the creation of new, and support the development of existing, cross-border R&D&I partnerships (including stakeholders from academic institutions, SMEs and Government agencies).

The aim of this investment priority (and its Specific Objective) is to utilise cross-border collaboration to increase the overall level of research and innovation competence and activity across the programme area in a strategic way designed to contribute towards the development of a more competitive, high value-added economy[5].

In order to achieve the aim of creating or enhancing research and innovation centres within the timeframe of the programme, the selection of sectors with existing capacity and capability was deemed to be essential. Therefore, it was decided that programme support would be directed towards two sectors: Life and Health Sciences; and Renewable Energy[6]. It is anticipated that this focused approach would further develop research areas in which there are existing critical mass and those where the region has distinct advantages (thereby aligning with the EU Smart Specialisation Platform).

The **output indicators**[7] for Objective 1.1 are set out below:[8]

- 514 years' worth of PhD (or above) level research
- 5 research institutions participating in cross-border, transnational or interregional research projects
- 20 enterprises receiving support
- 10 enterprises receiving grants
- 20 enterprises receiving non-financial support
- 10 enterprises cooperating with research institutions
- 10 enterprises participating in cross-border, transnational or interregional research projects

The INTERREG VA Citizens' Summary suggested that the above outputs might be achieved through the following **indicative actions**:

Table 1.2: Objective 1.1 Indicative Actions[9]
• The creation of clusters which will enable the development of virtual centres of excellence within the region, involving capacity and competence building; • Clusters will complement existing R&I strategies within jurisdictions by promoting cross-border cooperation and will take the form of partnership arrangements between existing institutions in academia, public sector agencies and private sector companies; • The further development of existing competence centres to facilitate increased levels of cross-border collaboration; and • The clusters will address market failure in the Research, Technology Development and Innovation (RTDI) landscape, whereby the risk associated with the longer-term nature of strategic research carried out cannot be addressed by individual companies.

[5] The term R&D encompasses three types of activities: basic research, industrial research and experimental development. However, only industrial research and experimental development activities are eligible for support under the INTERREG VA programme.
[6] Definitions of these sectors are provided in Appendix I.
[7] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).
[8] Each output indicator is defined in the 'Output Indicator Guidance' document for Objective 1.1.
[9] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).

The **result indicator**[10] for this Objective 1.1 is the annual number of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross-border authorship and with the potential to create economic impact. The stated baseline value for 2014 (i.e. the start of the Programme period) is 4, whilst the target value for 2023 is 75[11].

1.3.3 *Objective 1.2 – Increasing the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services*

The Co-operation Programme notes that a range of barriers contributes to the high level of innovation[12] inactivity that exists among SMEs in the eligible region including the cost of innovation, a lack of internal funds and a lack of external finance.

The aim of this investment priority (and its Specific Objective) is to build a strong export-based economy through increased awareness of, and engagement in, innovation activities by SMEs in the eligible region, specifically on a cross-border basis. In doing so the priority seeks to (inter alia):

- Increase the capacity of SMEs and micro-businesses to participate in cross-border research and innovation activities;
- Increase levels of investment in the creation of cross-border centres and projects designed specifically to strengthen the links between SMEs and Research Institutions;
- Increase the number of enterprises actively innovating to bring new products and/or new processes to the market; and
- Build systems and cultures of open innovation across the eligible region.

In order to achieve these objectives, the Co-Operation Programme considered that it would be necessary to engage in an intensive programme of development with SMEs and micro-businesses within the region; which might include businesses participating in one or more of the following activities:

Table 1.3: Strands of Activity anticipated to the undertaken as part of Objective 1.2[13]	
1. Preparatory Interventions delivered via workshops	An initial series of preparatory workshops for SMEs in the region, aimed at raising awareness of R&I and identifying those SMEs with potential to progress to more intensive development activities. This element describes a series of workshops to educate and influence SMEs on the importance of the innovation ecosystem enabling them to leverage this on a cross-border basis to advance their business. It is anticipated that these workshops will have cross-border participation and will serve to raise knowledge and awareness of other innovation actors and support systems across the border.
2. Preparatory Interventions delivered on a one to one basis	A more intensive preparatory intervention with individual SMEs, providing them with one to one advice and support in the identification of R&I opportunities. This element describes an in-firm activity to assess their current approach to innovation and how the local and cross-border innovation ecosystem is utilised. The output will identify specific areas where cross-border collaboration will be beneficial and the appropriate cross-border intervention for each individual SME. Where progression to strands 3 or 4 or 5 is not appropriate, SMEs will be signposted to alternative local and cross-border support mechanisms.

[10] The Programme's impact is monitored through the use of output and result indicators. Projects receiving funding through INTERREG VA are expected to report progress against output indicators only (Output Indicator Guidance document for Objective 1.1, January 2017).
[11] Source: Cooperation Programme for the INTERREG VA Programme 2014-2020.
[12] The CP defines innovation as the development of solutions that meet needs in new ways. The CP considers innovation to be wider than R&D in so far as it covers improvements to products, tradable services and processes.
[13] Source: Cooperation Programme for the IVA Programme 2014-2020.

Table 1.3: Strands of Activity anticipated to the undertaken as part of Objective 1.2[13]	
3. Innovation Capability Development Programme	Engaging with a targeted group of SMEs in an intensive R&I capability development programme. Participation in this element is optional and is dependent on the outcome of strand 2. Where participation does occur, the support provided will aim to address any internal barriers that will prevent the participating firms realising the full potential of the cross-border innovation providers and programmes.
4. Cross-border Innovation Internship Programme	Providing selected and targeted SMEs with the opportunity to avail of a cross-border internship programme that will make available to them a qualified graduate with the necessary skills to contribute to the R&I activity within their company.
5. Cross-border R&I Projects	Engaging targeted SMEs in cross-border R&I projects that have been identified as having significant potential for economic impact within their companies and within the economy of the region.

The **output indicators**[14] for Objective 1.2 are set out below:[15]

- 1,408 enterprises receiving support;
- 1,408 enterprises receiving non-financial support;
- 469 enterprises receiving one-to-one innovation advice;
- 5 research institutions participating in cross-border, transnational or interregional research projects;
- 94 enterprises in receipt of an Innovation Capability Development Programme;
- 70 enterprises engaging an Innovation Intern, on a cross-border basis.
- 50 enterprises cooperating with research institutions;
- 19 enterprises participating in cross-border, transnational or interregional research projects;
- 19 enterprises receiving grants.

It is stated that the above outputs could be achieved through the following **indicative actions**:

Table 1.4: Objective 1.2 Indicative Actions[16]

- Education and awareness-building programmes aimed at SMEs.
- One-to-one mentoring and advice programmes for SMEs.
- Innovation capability audits within SMEs.
- Development and implementation of innovation action plans tailored to the needs of the SMEs which address innovation capability deficiencies.
- Innovation internship programmes incorporating technology job creation, designed to address the capability deficiencies.
- A collaborative R&D programme designed to create and support collaborative research projects between SMEs and research institutions.

The **result indicator[17]** for Objective 1.2 is the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations. The stated baseline value for 2014 (i.e. the start of the Programme period) is 22%[18], whilst the target value for 2023 is 33%[19].

[14] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).
[15] Each output indicator is defined in the 'Output Indicator Guidance' document for Objective 1.2 (February 2016).
[16] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).
[17] The Programme's impact is monitored through the use of output and result indicators. Projects receiving funding through INTERREG VA are expected to report progress against output indicators only (Output Indicator Guidance document for Objective 1.1, January 2017).
[18] NB: To determine this baseline, SEUPB advised that specific questions were introduced into the January/February 2015 version of InterTradeIreland's quarterly All Ireland Business Monitor Survey. It is understood that 146 (22%, N=676) of the business respondents indicated that they undertook R&D&I and were supported by another organisation outside their own jurisdictions i.e. Northern Ireland, the border region of Ireland or Western Scotland. For the purposes of this paper (which focuses on cross-border collaborative R&D&I activity being between Northern Ireland and the border region of Ireland, excluding Scotland), SEUPB advised that 119 (22%, N=548) of the total business respondents based in either Northern Ireland (N=79) or border region of Ireland (N=40) indicated that they undertook R&D&I and were supported by another organisation outside their own jurisdictions i.e. Northern Ireland or the border region of Ireland.
[19] Source: Cooperation Programme for the IVA Programme 2014-2020.

1.3.4 *Summary of Specific Objectives, Result Indicators and Targets*

Table 1.5 provides a summary of the Specific Objectives, Result Indicators and Targets for Priority Axis 1: Research and Innovation:

Table 1.5: Summary of Specific Objectives, Results Indicators and Targets

Specific Objective	Result Indicator	Baseline	Target
1.1 To increase business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences and Renewable Energy	The annual number of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross-border authorship and with the potential to create economic impact	4	75
1.2 To increase the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services	The percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations	22%	33%

The anticipated Output Indicators are summarised below:

Table 1.6: Summary of Output Indicators

Output Indicator[20]	Objective		Total
	1.1	1.2	
No. of enterprises receiving support	20	1,408	**1,428**
No. of enterprises receiving grants	10	19	**29**
No. of enterprises receiving non-financial support	20	1,408	**1,428**
FTE Years of PhD (or above) level research	514	0	**514**
No. of enterprises cooperating with research institutions	10	50	**60**
No. of enterprises participating in cross-border, transnational or interregional research projects	10	19	**29**
No. of research institutions participating in cross-border, transnational or interregional research projects	5	5	**10**
No. of enterprises receiving one to one innovation advice	-	469	**469**
No. of enterprises in receipt of an innovation capability development programme	-	94	**94**
No. of enterprises engaging an innovation intern, on a cross-border basis.	-	70	**70**

1.4 The Evaluation – SEUPB's Requirements

To fulfil the requirement of Article 114(1) of the Common Provisions Regulation (EU No: 1303/2013), SEUPB's Managing Authority has submitted to the Commission an Evaluation Plan for the INTERREG VA Programme[21]. The Evaluation Plan has been put in place to facilitate learning and maximise the proposed investments of the Programme[22].

[20] Each output indicator is defined in the 'Output Indicator Guidance' documents for Objectives 1.1 and 1.2.
[21] The Evaluation Steering Group (ESG), a sub-group of the Programme Monitoring Committees for the PEACE IV and INTERREG VA Programmes, was established to ensure the effective implementation of the Evaluation Plan for each Programme.
[22] Article 56(3) of Regulation (EC) No: 1303/2013 requires that an evaluation should assess how the support provided has contributed to the achievement of the objectives of the programme. Article 54 requires the impact evaluation to comment on the contribution of the priority axis to the EU 2020 objectives. In addition, Article 7 of the above regulation requires that Member States ensure equality between men and women and the integration of a gender perspective are taken into account and promoted throughout the preparation and implementation of the programmes, including in the monitoring and evaluation of the programmes. Article 7 also specifies that the programme authorities must take appropriate steps to prevent any discrimination on any of the specified grounds. Article 8 requires that the objectives of the funds shall be pursued in line with the principle of sustainable development and with the European Union's promotion

The Plan outlines two types of evaluation:

1. **Implementation Evaluations** which will assess the efficiency and effectiveness of the implementation mechanism established for the programme (these will not form any part of this assignment); and

2. **Impact Evaluations** which will be carried out on each priority axis to test the intervention logic of that priority axis, and form a view of the effectiveness and impact of the investment.

In relation to the Impact Evaluations, the Plan states that the evaluations will assess achievements as regards effectiveness (the attainment of the specific objectives set and of the intended results), efficiency (the relationship between the funding disbursed and the results achieved) and impact (the contribution of the programme to the end objectives of the EU Cohesion Policy).

SEUPB has commissioned Cogent to undertake a longitudinal Impact Evaluation of Priority Axis 1 – Research and Innovation to include 3 reports due by end of 2018, end of 2020 and early 2022[23].

The overall focus of the evaluation is to assess (at three stages of implementation), the impact of the interventions within the 'Research and Innovation' Priority Axis. As a full implementation evaluation is being undertaken across INTERREG VA concurrently with the Impact Evaluation, **the Impact Evaluation does not seek to assess the implementation of projects nor how the Programme is operating. Rather than addressing financial and operational issues,** the purpose of the impact evaluation is learning, through an exploration of the contribution of the Programme to the movement of the Result Indicator, to inform the remainder of the INTERREG VA Programme and potential future programming periods.

As such, the Impact Evaluation Team is required to address the following:

- To what extent have the Specific Objectives been achieved?
- To what extent have the targets for the Result Indicators been achieved?
- Comment on the effectiveness and added value of cross border collaboration in relation to the Specific Objectives?
- What external factors have impacted, positively or negatively, on the achievement of the Specific Objectives?
- Were the two target sectors appropriate?
- What synergies have there been between projects funded under both objectives;
- How have collaborations affected the quality and capacity for research and innovation in the eligible area?
- What has the impact been on business and industry?
- What has been the impact of cross-border collaborations under both objectives?
- What new ways of working/partnerships/relationships have been created as a result of activities carried out within the priority axis?
- Identify key areas of best practice and learning;
- Are there barriers to cross-border cooperation that the priority axis is not addressing?
- What is the contribution of the priority axis to[24]:

  – EU 2020 objectives;
  – The Atlantic Strategy; and
  – The horizontal principles of equality and sustainable development?

of the aim of preserving, protecting and improving the quality of the environment taking into account the polluter pays principle.

[23] The report received in 2022 will include a summary of all previous findings and will contribute directly to the programme summary of evaluation findings, to be submitted to the EU Commission.

[24] NB An overview of the aims and objectives of these strategies is provided in Appendix II.

2. OVERVIEW OF PROGRAMME ACTIVITY AND SUPPORTED PROJECTS

2.1 Introduction

Section 2 provides a high-level overview of the programme activity and projects supported under Priority Axis 1 of the INTERREG VA Programme.

2.2 Overview of Programme Activity

There were two calls for applications under Priority Axis 1: Research and Innovation. A two-stage process[25] was then initiated by the SEUPB's Joint Secretariat to assess applications submitted under each of the calls. Full details of the assessment process, including admissibility criteria, were outlined for applicants in the 'Call Documentation' and the 'Guide for Applicants'. Further details on the calls and applications received at each stage are presented below:

Table: 2.1: Applications Received and Approved

Objective	Call opened	Call closed	Applications received		Applications approved
			Stage 1	Stage 2	
1.1	21st March 2016	6th May 2016	10	7	**7**
1.2[26]	7th September 2015	21st October 2015	3	2	**1**

Further details on the 8 projects approved by the IVA Programme Steering Committee[27] are included in Tables 2.2 and 2.3:

Table 2.2: Summary of Projects Approved for Funding[28]

Lead Partner	Project Name	Project Cost (€)
Objective 1.1		
Dundalk Institute of Technology	BREATH (Border and Regions Airways Training Hub)	€8,506,929
South West College	Renewable Engine	€6,104,995
Catalyst Inc.	North West Centre for Advanced Manufacturing	€8,779,853
Ulster University	Eastern Corridor - Medical Engineering Centre (ECME)	€8,362,917
Ulster University	Storage Platform for the Integration of Renewable Energy (SPIRE 2)	€6,703,246
Ulster University	Centre for Personalised Medicine: Clinical Decision Making and Patient Safety (CPM)	€9,424,927
Queen's University Belfast	The Bryden Centre for Advanced Marine and Bio-Energy Research	€9,752,680
Subtotal		**€57,635,547**
Objective 1.2		
InterTradeIreland	Co-Innovate (The Innovation Pathway Programme)	€22,443,035
Total		**€80,078,582**

[25] Stage one - short application form and admissibility checks. Stage two – submission of full business plan and associated appendices (prepared in line with SEUPB's Business Plan Guidance).
[26] The Call Documentation indicated that only one applicant, that could successfully demonstrate that their project proposal would deliver all of the Output Indicators under this specific objective, would be awarded funding. Applicants who could not deliver the output indicator targets in full were advised not to apply.
[27] The decision as to whether to fund a project rested entirely with the IVA Programme Steering Committee.
[28] Projects were approved at IVA Programme Steering Committees held on: 6/9/2016, 7/9/16, 23/11/2016 and 14/3/2017.

Table 2.3: Summary of Projects Approved for Funding[29]							
Project Ref	**Lead Partner**	**Project Name**	**Operational start date**	**Operational end date**	**Project Cost (€)**	**ERDF Allocation (€)**	**ERDF Allocation %**
Objective 1.1							
045	Dundalk Institute of Technology (DIT)	BREATH (Border and Regions Airways Training Hub)	01/01/2017	31/12/2021	€8,506,929	€6,781,065	79.7%
046	South West College	Renewable Engine	01/01/2017	31/07/2021	€6,104,995	€5,067,817	83.0%
047	Catalyst Inc.	North West Centre for Advanced Manufacturing	01/04/2017	31/12/2021	€8,779,853	€7,462,875	85.0%
048	Ulster University	Eastern Corridor - Medical Engineering Centre (ECME)	01/03/2017	31/12/2021	€8,362,917	€7,108,480	85.0%
049	Ulster University	Storage Platform for the Integration of Renewable Energy (SPIRE 2)	01/03/2017	31/12/2021	€6,703,246	€5,668,754	84.6%
052	Ulster University	Centre for Personalised Medicine: Clinical Decision Making and Patient Safety (CPM)	01/04/2017	31/12/2021	€9,424,927	€7,415,033	78.7%
053	Queen's University Belfast	The Bryden Centre for Advanced Marine and Bio-Energy Research	01/06/2017	31/12/2021	€9,752,680	€8,289,778	85.0%
Subtotal					**€57,635,547**	**€47,793,802**	
Objective 1.2							
003	InterTradeIreland	Co-Innovate (The Innovation Pathway Programme)	01/08/2016	31/03/2022	€22,443,035	€14,702,502	65.5%
Total					**€80,078,582**	**€62,496,304**	

The anticipated contribution that each of the 8 projects would make to the Priority's key Output Indicators is detailed

Table 2.4: Projects Approved for Funding – Stated Contributions to Output Indicators (source: Letters of Offer issued by the SEUPB)									
Output Indicator	**Project Ref**								**Total**
	1.1							**1.2**	
	045	**046**	**047**	**048**	**049**	**052**	**053**	**003**	
No. of enterprises receiving support	5	8	8	10	12	5	30	1,408	**1,486**
No. of enterprises receiving grants	2	4	2	5	2	3	8	30	**56**
No. of enterprises receiving non-financial support	5	8	8	10	12	5	30	1,408	**1,486**
Years of PhD (or above) level research	89.5	57.05	98.5	95	83	80.5	132.5	n/a	**636**
No. of enterprises cooperating with research institutions	5	8	8	10	12	5	30	50	**128**
No. of enterprises participating in cross-border, transnational or inter-regional research projects	2	8	8	10	12	5	30	30	**105**
No. of research institutions participating in cross-border, transnational or inter-regional research projects	3	4	4	5	4	4	5	5	**34**
No. of enterprises receiving one to one innovation advice								469	**469**
No. of enterprises in receipt of an innovation capability development programme								94	**94**
No. of enterprises engaging an innovation intern, on a cross-border basis								70	**70**

[29] Source: Letters of Offer issued by the SEUPB.

2.3 Reasonableness of Targets and Indicators

Based on its review of the output and result indicators/targets established for the Investment Priority, the Evaluation Team makes the following observations in relation to their reasonableness:

- Whilst noting that that the Common Output and Results Indicators have been set by the Commission and agreed by Member States to support EU-wide measurement and comparison, when viewed in the context of the Evaluation logic chain - which illustrates the intrinsic linkages between an intervention's aims, inputs, activities, outputs and outcomes – the output indicators appear to more overly representative of the 'activities' and 'inputs' being delivered under the Priority Axis, whilst the Results Indicator identified under Specific Objective 1.1 is more overtly representative of an 'Output'.

Figure 2.1: The logic chain to Evaluation

Whilst the Northern Ireland Guide to Expenditure Appraisal and Evaluation (NIGEAE) and Green Book guidance reflects the importance of establishing activity-based targets, these should be viewed as a 'means-to-an-end'. That is to say, their delivery should be seen as an important step in facilitating the ultimate achievement of an intervention's stated outputs, outcomes and ultimate aims (in this case the overarching Specific Objectives). In this regard, caution should be taken in utilising the stated output targets that have been established for the Investment Priority as an indicator that the Priority Axis has ultimately delivered value-for-money.

- On review of the number and nature of Common Output indicators, we are of the view that the Commission should have adopted fewer (or different) specific targets/indicators as (for those established) the delivery of a single element of activity offers the potential to contribute to the achievement of multiple indicators and, in doing so, may potentially create a 'false' sense of achievement in the context of what has actually been delivered under the Investment Priority. For example, a business that has received financial support to engage in research and innovation activities with a cross-border academic institution may potentially contribute to the achievement of five of the seven Common Outputs indicators for Specific Objective 1.1 i.e.:

  - No. of enterprises receiving support
  - No. of enterprises receiving grants
  - No. of enterprises receiving non-financial support
  - No. of enterprises cooperating with research institutions
  - No. of enterprises participating in cross-border, transnational or interregional research projects.

To illustrate the previous two points, and given the nature of the intervention, we have identified the types of targets/indicator that could have been established and monitored by Project Promoters in Table 2.5 below. In doing so, each has been considered in the context of each stage of the Evaluation logic chain:

Table 2.5: Examples of indicators/targets along to Evaluation logic Chain	
Stage of the logic chain	**Potential Indicators/targets**
Aims	• To increase business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences and Renewable Energy (Specific Objective 1.1) • To increase the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services (Specific Objective 1.2)
Inputs	• Level of funding awarded per project • Time provided by businesses • Time provided by academia including FTE Years of PhD (or above) level research
Activities	• The nature and number of the R&D projects that have been undertaken (incl. the TRL targeted) • The extent of R&D&I, collaborative working and/or networking activities being undertaken by industry and academia before and after receiving support • Nature of collaborative activities taken forward as a result of the collaborative activity e.g.: – Shared information/knowledge – Shared facilities – Shared equipment – Shared raw materials – Established new business contacts – Jointly tendered to win larger and/or more contracts – Jointly managed a supply chain – Identified good/best practice – Availed of other business' complementary strengths and capabilities – Increased your scale of operations through the creation of economies of scale – Supported you to exploit emerging regional, national and international market opportunities • Nature of any R&D&I undertaken before and after receiving support (e.g. basic research, experimental development industrial research) • Levels of 'activity' additionality - Degree to which businesses would have engaged in collaborative R&I with an academic institution and/or with another industrial partner (s) (where relevant)
Outputs	• No. of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross-border authorship and with the potential to create economic impact • No. of prototypes/demonstrators developed • No. of license agreements issued • No. of spin-offs/Spinouts (and spin-ins if relevant) • No. of invention disclosures • No. of patents awarded • No. of new product/process or services developed • No. of existing product/process or services adapted • PhDs/Masters awarded • New products and/or processes created • Adapted products and/or processes created • Mobility of Staff (between partners) • Number of workers upskilled • No. of new potential new customers and/or suppliers identified • New geographic and/or sectoral markets entered into • Leveraging of other further funding
Outcomes and Impacts	• Safeguarded turnover • Increased sales in domestic, external and export markets • Reduction in costs • Increased employment (FTEs) within the business • Employment Safeguarded/Retained • Increased expenditure on Research, Development and Innovation (R&D&I)

Table 2.5: Examples of indicators/targets along to Evaluation logic Chain	
Stage of the logic chain	**Potential Indicators/targets**
	• Improved the skills of the business' workforce; • Increased competitiveness; • Increased productivity/efficiency; • Impact on the business' survival; • No of innovation active/inactive SMEs; • Impact of the project on R&I culture, mindsets and behaviours: – Businesses' commitment to engaging in R&D&I; – Businesses' understanding of the benefits of working collaboratively with academia and/or other businesses; – Businesses likelihood of engaging in collaborative research activities with other academic institutions and businesses in the future; – Business' confidence in engaging collaborative research activities; – Business' capacity to undertake collaborative R&I has increased; – Business' capability to undertake collaborative R&I has increased; – The degree to which collaboration now represents a more fundamental part of the business' growth strategy.

Ultimately, the Evaluation Team is of the view that many of the aforementioned issues could potentially have been addressed had the project applications been robustly independently economically appraised.

- The overall Results Indicator for Specific Objective 1.1 is to increase the annual number of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross-border authorship and with the potential to create economic impact from 4 to 75 by 2023. In relation to this we note the following:

  – Based on the INTERREG VA Operational Programme, the Evaluation Team understands that the Managing Authority carried out a survey-interview of higher education institutions in the region to establish the number of peer-reviewed journals and conference publications to establish the annual baseline (which was subsequently identified as 4). However, based on the outputs from their own research activity, a number of Project Promoters questioned the source of the identified baseline, suggesting the number appeared low, and by association then, potentially served to overinflate the potential impact that would be made by the Investment Priority.

  – Given the fact that the annual number of peer-reviewed journal and conference publications would likely ramp-up in line with the levels of research activity being undertaken, in retrospect it would have been beneficial for annual quantified targets to have been established to ensure that progress could be measured towards the annual 2023 target at different annual points (as opposed to in 2023).

  – Based on our discussion with Project Promoters, our review of SEUPB's LoOs and Project Assessment materials and completed monitoring materials, ambiguity exists as to the specific nature of the Result Indicator. Whilst noting that the Results indicator indicates that the quantified target relates to the annual number of peer-reviewed journal and conference publication, our review of SEUPB Stage 1 and 2 Assessment reports for individual projects appears to indicate that this target is being interpreted in terms of cumulative rather annual outputs. For example, per the Table below, it was anticipated that the Bryden Centre Project would contribute 68 of the 75 peer-reviewed journal and conference publications, equivalent to 91% of the target. However, our discussion with Project Promoters and review of their monitoring materials suggest that this target is being interpreted as being the total number of publications that the project would contribute, as opposed to the annual number in 2023.

Table 2.6: Results indicator for the Bryden Centre			
Result Indicator	**Programme Target**	**Project Target**	**% Contribution**
The annual number of peer-reviewed journal and conference publications in two sectors (Health and Life Sciences and Renewable Energy) with cross border authorship and with the potential to create economic impact.	75	68	91%

– It is unclear as to how a publications potential to 'create economic impact' could be measured in practice or its usefulness as the overall indicator to show progress towards the overarching Specific Objective 1.1 which is overtly focused on increasing business and industry-relevant research and innovation capacity.

- NIGEAE and Green Book guidance indicates that 'Efficiency'- the degree to which an intervention has achieved the maximum output from a given set of inputs - is a key measure of determining the value-for-money that has been provided by an intervention. On consideration of the scale of investment made at an individual project level and the Output and Results Indicators that have been established, the Evaluation Team would have reservations as to whether SEUPB has the potential to fully deliver on this indictor of value-for-money. For example, if the Results indicator is reflective of the total number of peer-reviewed journal and conference publications (as opposed to the annual number), the fact that the Bryden Centre project is potentially contributing 91% of the overall target suggests that the scale of the target is, in retrospect too low, and SEUPB could potentially have derived additional outputs by identifying a relatively higher target.

  Similarly, the number of enterprises (N=20) anticipated to be supported through Specific Objective 1, appears low given the quantum of funding being provided and when viewed in the context of other similarly focused interventions available within the eligible region (e.g. Invest NI's Competence Centre Programme, Grant for R&D Programme etc.) and the overall focus of the Specific Objective.

- The Evaluation Team is of the view that greater focus should have been placed on ensuring that the Results indicator associated with Specific Objective 1.2 adhered to the 'SMART' (Specific, Measurable, Achievable, Realistic and Timebound) principles. Whilst the Evaluation Team is not privy to the target setting methodology or sources of information that was adopted/utilised by SEUPB to quantify the Results indicator target, if read literally, the scale of the target appears unachievable in the context of the support that is anticipated to be delivered through the Co-Innovate Programme. For example, in consideration of NI alone, we note that there were 67,235 SMEs in NI in 2014 (the baseline year). To achieve 33% of SMEs engaged in research and innovation involving cross-border collaboration in this region would require support to be provided to 7,396. However, the maximum number of SMEs anticipated to benefit from Co-Innovate support is 1,428 (leaving a shortfall of 5,968 within the NI element of the eligible regional alone).

Table 2.7: Calculation of the potential contribution of the Co-Innovate Programme	
Total SMEs in NI (2014[30])	67,235
No. estimated to be engaged in research and innovation involving cross-border collaborations during the baseline period (22% of SMEs)	14,792
No. estimated to be engaged in research and innovation involving cross-border collaborations during the baseline period (33% of SMEs)	22,188
No. of SMEs required to benefit from Co-Innovate support to achieve the Result Indicator target	7,396
Maximum no. of SMEs anticipated to benefit from Co-Innovate support	1,428
Difference between no. of SMEs required to benefit from Co-Innovate support to achieve the Result Indicator target and the maximum no. of SMEs anticipated to benefit from Co-Innovate support	5,968

[30] Source: NI Inter-Departmental Business Register - Number of Private Sector VAT and/or PAYE Registered Businesses Operating in NI

In addition, it is unclear as to why the target has been limited to the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations on the basis that the project is ultimately seeking to support SMEs within the entirety of eligible region (including SW Scotland and the Highlands and Islands) and project delivery is being taken forward on this basis (as well as being included by the Project Promoter against the Results indicator target). As such, greater attention should have been given to ensuring this indicator was more 'achievable' and 'realistic'.

3. NWCAM - NORTH WEST CENTRE FOR ADVANCED MANUFACTURING

3.1 Introduction

This section of the report considers the North West Centre for Advanced Manufacturing (NWCAM) project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry relevant research and innovation capacity across the region.

3.2 Project Overview

3.2.1 *Background*

The North West Centre for Advanced Manufacturing (NWCAM) project aims to address several economic deficiencies and opportunities including:

- The need to redress the economic imbalance and improve the North West region's economic performance;
- Low levels of Business Expenditure on Research and Development (BERD) and the need for regional investment in R&I;
- Deficiencies in the Triple Helix Model – According to the project partners, with regard to R&I, the Triple Helix Model (comprising the Public Sector; Academia; and the Private Sector) was not delivering the desired level of commercialisation and economic impact. They noted that research[31] had identified the benefits of 'Innovation Brokerage'. The main task of the Innovation Broker to set up a multiplicity of Operational Groups around viable R&I projects. The Broker is not necessarily involved in the actual innovation project: his/her core objective is to help the group in the elaboration of a well-designed project plan. Ideally, innovation brokers should have a good connection to and a thorough understanding of the target sector as well as well-developed communication skills for interfacing and animating. An important asset of an innovation broker should be to look cross-sectoral and connect across the existing institutes, disciplines, viewpoints etc.[32]
- The importance of the regional Health and Life Sciences sector;
- The increasing potential of Advanced Manufacturing R&I - Advanced Manufacturing is the use of innovative technologies and materials to improve products or processes. All sectors globally are now dominated by a multitude of advanced materials. Economic growth increasingly depends on advances in the application of advanced manufacturing, since many technological advances can only be achieved in this way. The potential of the sector to the Region is highlighted in the MATRIX reports issued in 2008 and 2016; within the latter it states:

  "Advanced Manufacturing has a considerable influence on maintaining a leading technology position and thus on the creation of jobs'. Industries that are significant to the Region, including Health and Life Sciences, should look to Advanced Materials and Engineering to enhance their capability".

  According to the NI Advanced Materials Matrix Panel, given its Manufacturing prowess, with *"appropriate investment in related R&I, the Region could achieve a step-change in advanced materials and engineering thinking with the potential to offer significant economic impact in a European and Global Context"*[33].

The project partners considered that these opportunities were particularly key to the eligible region, which has established strength in manufacturing and advanced manufacturing. However, according to the project partners, whilst the MATRIX report had identified the potential of advanced manufacturing to advance the regional Health and Life Sciences sector, their consultations, whilst developing their INTERREG funding application, had found a lack of understanding regarding the potential of Advanced Manufacturing as an enabling technology.

[31] http://enrd.ec.europa.eu/enrd-static/app_templates/enrd_assets/pdf/researchandinnovation /FG_KTI_Phase_2_report_IB_Web_version_September_2013_Main_Report.pdf
[32] http://www.innovationunit.org/sites/default/files/Honest%20Brokers.pdf
[33] http://matrixni.org/wp-content/uploads/2015/02/MATRIX-life-and-health-sciences-foresight-report-2015.pdf

3.2.2 The NWCAM Project

The North West Centre for Advanced Manufacturing (NWCAM) project aims to create an Advanced Manufacturing supercluster combining the collective and complementary strengths of the Engineering Research Institute at Ulster University; the James Watt Nanofabrication Centre at Glasgow University; the PEM Centre at Sligo Institute of Technology; and CoLab at Letterkenny Institute of Technology; co-ordinated by Catalyst Inc.

The Vision for the Project is:

> *"To create an Advanced Manufacturing supercluster combining the collective and complementary strengths of the Engineering Research Institute at Ulster University; the James Watt Nanofabrication Centre at Glasgow University; the PEM Centre at Sligo Institute of Technology; and CoLab at Letterkenny Institute of Technology; co-ordinated by Catalyst Inc".*

The project's design is based on leveraging collective academic strength in the area of Advanced Manufacturing and applying this to support the level of R&I undertaken by companies predominately located in the North West area of the eligible region[34].

This will see the development of a virtual cross border Centre for Advanced Manufacturing with a focus on four thematic areas[35] for application within the Health and Life Sciences Sector:

1. Sustainable Manufacturing	This is the creation of manufactured products through economically-sound processes with minimal negative environmental impact. Products are manufactured through processes that prevent Green House Gases (GHGs) conserve energy and natural resources, and that are non-hazardous to employees and consumers. In addition to the environmental advantages of developing and adopting sustainable manufacturing processes, in most instances, they facilitate significant financial savings, which allow regional firms to become more internationally competitive. This is a research competence area of ITS and UU.
2. Advanced Polymers	A polymer is a large molecule or macromolecule, composed of many repeated subunits. Because of their broad range of properties, both synthetic and natural polymers play an essential and ubiquitous role in everyday life. Polymers range from familiar synthetic plastics such as polystyrene to natural biopolymers such as DNA and proteins that are fundamental to biological structure and function. Polymers both natural and synthetic are created via polymerisation of many small molecules, known as monomers. The consequently large molecular mass relative to small molecule compounds produces unique physical properties, including toughness, viscoelasticity and a tendency to form glasses and semi-crystalline structures. This is a research competence area of UU and ITS.
3. Additive Manufacturing	Also referred to as 3D printing, additive manufacturing is any of various processes used to make a three-dimensional object. In 3D printing, additive processes are used, in which successive layers of material are laid down under computer control. These objectives can be of almost any shape or geometry and are produced from a 3D model or other electronic data sources. 3D printing in the term's original sense refers to processes that sequentially deposit material onto a powder bed with inkjet printer heads. More recently, the meaning of the term has expanded to encompass a wider variety of techniques such as extrusion and sintering based processes. This is a research competence area of UU and LyIT.

[34] For example: Nuprint; Sphere Global; Armstrong Medical; and Bemis Healthcare Packaging (all Derry/Londonderry); GSK Stiefel; and Abbott (both Sligo) and Randox (Donegal). In addition, it is noted that while C-I and UU have locations in the Greater Belfast area, both organisations are also located in the North West area of the Region: CI within the North West Regional Science Park in Derry / Londonderry; and UU at its Magee campus in Derry / Londonderry. It is understood that a significant element of the proposed investment will be directed to these locations.

[35] NB In order to help ensure success, the project partners considered that it was important that they selected those areas of advanced manufacturing, in which they had the most competence; and were the most relevant to the target sectors. On this basis, the NWCAM is concentrating efforts on a select number of advanced manufacturing competence areas, in which the academic partners were previously engaged in high level research activities.

4. Nano Manufacturing.	Manufacturing at the nanoscale is known as nano-manufacturing. This involves scaled-up, reliable and cost-effective manufacturing of nanoscale materials, structures, devices and systems. It also includes research, development and integration of top-down processes and increasingly complex bottom-up or self-assembly processes. In simple terms, nano-manufacturing leads to the production of improved materials and new products. There are two basic approaches to nano-manufacturing, either top-down or bottom-up. Top-down fabrication reduces large pieces of materials all the way down to the nanoscale. This approach requires larger amounts of materials and can lead to waste if excess material is discarded. The bottom-up approach to nano-manufacturing creates products by building them up from atomic- and molecular-scale components, which can be time-consuming. Exploration is ongoing regarding the concept of placing certain molecular-scale components together that will spontaneously "self-assemble," from the bottom up into ordered structures. This is a research competence area of UG and ITS.

This virtual Centre will span the Region but operate out of the North West; thereby seeking to redress the underinvestment in R&I in this part of the Region; and provide access to cutting edge research expertise to a number of Tier 1, 2 and 3 companies located there. Eight industry partners have been identified, consulted and participated in the co-design of the proposed research programme, together with the academic partners.

NWCAM is led by Catalyst Inc (the trading name of Northern Ireland Science Park Holdings Ltd) and involves a number of academic and industrial partners, including:

• Catalyst Inc (Lead Partner); • Ulster University (Lead Academic Partner): • University of Glasgow; • Institute of Technology Sligo; • Letterkenny Institute of Technology; • Derry City and Strabane District Council.	Industrial Partners / Beneficiaries[36] • Abbott; • Armstrong Medical; • Laser Prototypes Europe; • GSK Stiefel; • Leckey • Nuprint; • Denroy Plastics Ltd. • axial 3D • Causeway Sensors

In order to achieve their project objectives, the project partners are anticipated to undertake the following activities.

- **Co-ordination of Cross Border Research Team -** The core Project Team (comprising the Principal Investigator (PI), all the Co-Investigators (CI) from the academic partners, the Programme Manager and two Innovation Brokers) will meet on a quarterly basis. The purpose of these meetings will be to ensure that all members of the Project remain updated and opportunities for cross research synergies are identified as early as possible. These meetings will be chaired by the PI (Professor Harkin Jones). Related reports will be co-ordinated for presentation to the Project Board. This entity will also meet on a quarterly basis and be Chaired by Catalyst Inc's (C-I's) Financial Director.

- **Management of 15 R&I Projects with 9 Regional Industrial Partners -** In order to achieve the stated objectives, the Project Partnership will implement 15 R&I projects in partnership with nine regional companies within the Regional Life and Health Sciences Sector (including supply chain companies). The projects will encompass four specific areas of Advanced Manufacturing; Advanced Polymers; Additive Manufacturing; Nano-manufacturing; and Sustainable Manufacturing.

[36] Other businesses that were initially engaged with the project included Randox Laboratories, Sphere Global and Bemis Healthcare Packaging. Further information on the reasons for leaving the project are detailed in Section 3.5.5.

An overview of each of the 15 R&I Projects is outlined in Table 3.1. The implementation of the projects will require the recruitment and management of 13 PhD students and 11 PDRA staff.

- **Innovation Management Activities -** The aim of the R&I project activities outlined in Table 3.1 is the creation of the 15 new products and or processes. Central to the suggested operation of the project is the role of C-I, to forge a more effective link between academic and industrial partners and as such it is leading the Innovation Management dimension of the project. Arrangements are in place for IP management which covers knowledge management, confidentiality obligations, background, ownership and transfer of ownership of results, protection and exploitation of results, dissemination, access rights and settlement of disputes. Costs have been included to manage the process of IP. IP is being managed through all stages of the project, with significant input at the proposal stage and will continue through grant preparation, project implementation, exploitation and dissemination of results stage and conclusion of the project. These activities will be managed by two C-I appointed Innovation Brokers, who are responsible for providing related quarterly reports to the Project Team and Project Board. The partners have adopted the Innovation Management IP agreement model utilised within the NI Competence Centres.

- **Preparation of 30 peer-reviewed journal articles with cross-border authorship** – It is anticipated that these will illustrate the commercially beneficial application of Advanced Manufacturing technologies within the Health and Life Sciences and other key regional sectors. Each Thematic Lead will be responsible for coordinating the production and publication of these articles. This process will be overseen by the PI and related reports received at the quarterly Project Team and Board meetings.

A diagrammatical overview of the NWCAM Project is presented below:

Figure 3.1: Overview of the NWCAM Project

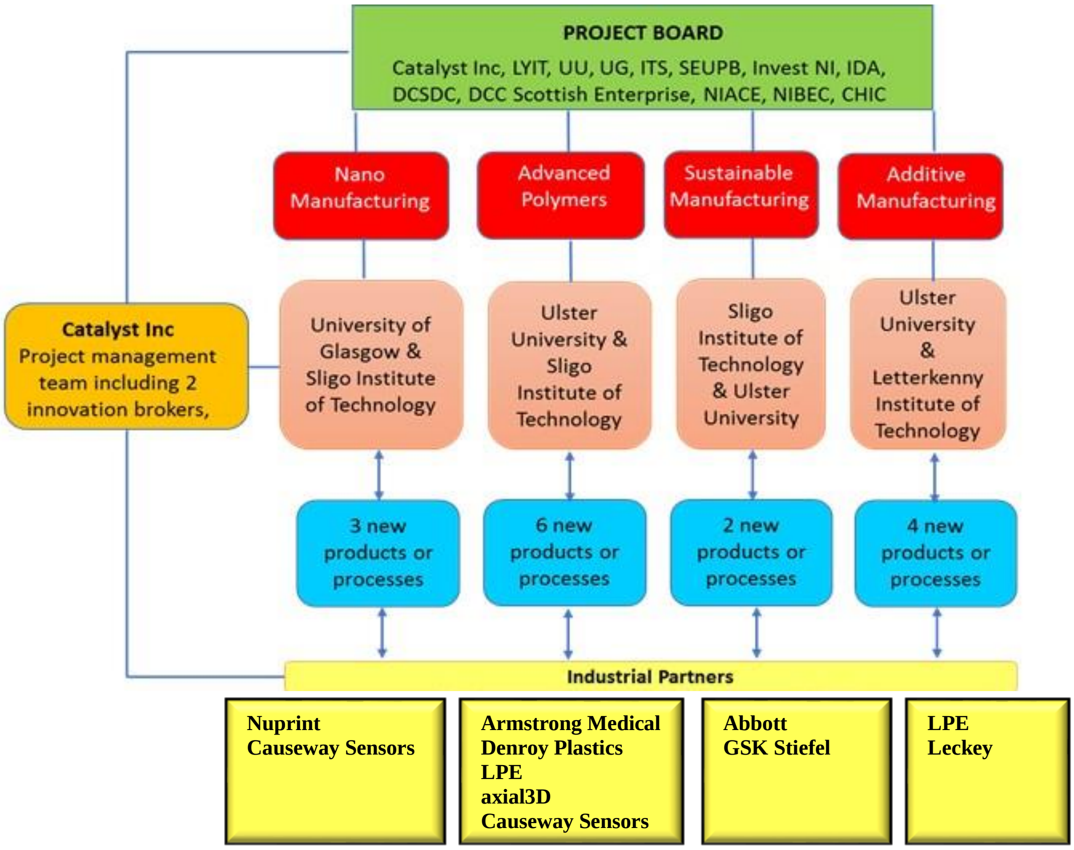


Table 3.1: Overview of the Proposed R&I Projects

	Project No.	Title	Aim	Driver	Industrial Partner	R&I Partners	Resources
Advanced Polymers	1	Development of insulated medical tubing with controlled gas barrier properties.	To develop tubing that will prevent condensation of H_2O vapour in the tube, allow H_2O to migrate to the outside of the tube yet retain other gases inside the tube.	Current problems with the condensation of H_2O and its accumulation inside the tubing.	Armstrong Medical	UU (Jordanstown)	3 PDRA yrs.
Advanced Polymers	2	Improving the processability and performance of polypropylene parts.	To develop an understanding of how processing, the inclusion of common pigments and processing additives influence the structure and properties of polypropylene parts.	There are problems with the consistency of quality of injection moulded parts when processing conditions change or when additives are included. Examples include inconsistent shrinkage and mechanical properties with different pigments and/or cooling rates. It is important to determine why these inconsistencies occur and determine methods to prevent or control these effects.	Armstrong Medical	UU (Jordanstown)	3 PhD yrs.
Advanced Polymers	3	Development of high-performance (Polyether ether ketone) PEEK Composite.	To develop new materials that are potentially recyclable and also experimenting to improve the performance of current materials used in their products.	Historically PEEK has been used in highly demanding applications such as automotive, aerospace and the chemical process industry. However, there is a lack of understanding about its use in biomedical and medical applications which could potentially open up significant market opportunities for industry.	Denroy	UU (Jordanstown	3 PDRA yrs.
Advanced Polymers	4	Assessment of recyclability of multifunctional PEEK composites.		Government and public policy are asking plastics industries to take greater responsibility for the types of polymer-based materials they use in their products in order to reduce their carbon footprint. Understanding the recyclability of innovative PEEK composites in industry after their initial function is vital for companies from both an environmental and sustainability point of view.	Denroy	UU (Jordanstown	3 PhD yrs.
Advanced Polymers	5	Development of advanced materials for additive manufacturing of medical devices and components.	To develop advanced engineering materials for additive manufacturing processes.	Few engineering-grade materials are available for additive manufacturing.	Laser Prototypes Europe (LPE)	UU (Jordanstown)	4 PDRA yrs. and 3 PhD yrs.
		Integration of Injection Moulded Plasmonic Nanostructures into a Biosensor Device (Project A).	To develop a unique polymer casing for a point of care microfluidic diagnostic biosensor device which will be used for rapid testing of		Causeway Sensors	UU (Jordanstown)	3 PhD yrs.

Table 3.1: Overview of the Proposed R&I Projects							
	Project No.	**Title**	**Aim**	**Driver**	**Industrial Partner**	**R&I Partners**	**Resources**
			diseases such as sepsis and tuberculosis.				
Advanced Polymers	6	Characterisation of additive manufacturing polymers for use in advancing surgical practice.	To develop polymer materials that can be used to advance surgical practices, in particular, medical 3D printable bioimplants at Point of Care (PoC) in a hospital setting.	Commercially available biomaterials used in craniofacial repairs such as metals, ceramics and polymers have a number of drawbacks including the high cost of manufacturing. Metals such as titanium can be too heavy, conduct heat and are expensive; ceramics tend to be brittle resulting in load-bearing issues and commonly used polymers although highly compatible and cheap have issues with tissue adhesion. The need for new bio implantable materials which can be inexpensively manufactured using a suitable 3D operational system in a hospital environment is growing.	axial3D	UU (Jordanstown)	2 PDRA yrs. and 3 PhD yrs.
Additive Manufacturing	7	Optimisation of the laser sintering of metal parts for medical products.	To optimise the current processing of metal components to ensure consistency of part properties and maximise process productivity.	There is currently little knowledge of process/material/property interactions and also relatively low productivity levels for metal sintering.	Laser Prototypes Europe (LPE)	UU (Magee)	2 PDRA yrs. and 3 PhD yrs.
Additive Manufacturing	8	Development of process simulation models for metal laser sintering.	To develop models to simulate to laser sintering of metals.	There is little or no process simulation available for additive manufacturing, yet such simulations are essential for the development of the process and new materials. Major commercial potential exists for such models.	Laser Prototypes Europe (LPE)	UU (Magee)	3 PDRA yrs. and 3 PhD yrs.
Additive Manufacturing	9	Development of process simulation models for laser sintering and fused deposition modelling of polymers.	To develop process simulation models for laser sintering and Fused Deposition Modelling of polymer parts.	There is little or no process simulation available for additive manufacturing, yet such simulations are essential for the development of the process and new materials. Major commercial potential exists for such models.	Laser Prototypes Europe (LPE)	UU (Magee)	3 PDRA yrs. and 3 PhD yrs.
Additive Manufacturing	10	Development of a new additive manufacturing machine to enable the use of engineering polymers and larger part builds.	To develop a new additive manufacturing machine with the capability to process engineering polymers such as PEEK and PEEK composites at a scale larger than currently feasible.	Additive manufacturing is severely limited in the materials it can currently process and also in the size of build possible. This project will utilise the expertise of Sphere global in advanced robotics to manufacture a prototype machine that will meet these needs.	Leckey	LyIT (Lead) and UU (Magee)	5 PDRA yrs. and 3 PhD yrs.

Table 3.1: Overview of the Proposed R&I Projects							
	Project No.	**Title**	**Aim**	**Driver**	**Industrial Partner**	**R&I Partners**	**Resources**
Nano-manufacturing	11	Printing of Electronic Layers and Devices on Flexible substrates.	To determine the potential of material suitability and inks to enable the printing of electronic circuitry on flexible surfaces.	Standard bar codes are limited in what they can be attached to. Within the health sector, it is imperative that reliable labelling is used on a variety of surfaces that gives health care providers confidence of traceability and assurance of travel of samples. Smart labels can be used in pharmaceutical and healthcare industries to track usage, travel temperatures, control stock or monitor the dampness of bandages.	Nuprint	UG	3 PDRA yrs. and 3 PhD yrs.
Nano-manufacturing	12	Smart printed RFID Sensor Tags for Health Monitoring.	To determine the best process and inks to enable the printing of electronic circuitry on flexible labels.	Standard bar codes are limited in what they can store but printed sensors can provide real-time information on location, temperature, moisture etc; allowing producers to prevent spoilage during transport or validate authenticity or shelf life. In shipping, tracking could be done at item rather than pallet level. Smart labels can be used in the pharmaceutical and healthcare industries to track usage, control stock or monitor the dampness of bandages.	Nuprint	UG	2 PDRA yrs. and 3 PhD yrs.
Nano-manufacturing	13	Integration of Injection Moulded Plasmonic Nanostructures into a Biosensor Device (Project B).	To develop a unique polymer casing for a point of care microfluidic diagnostic biosensor device which will be used for rapid testing of diseases such as sepsis and tuberculosis.	There is an unmet need for accurate, rapid and economical detection of deadly pathogens in a point of care environment. This opens up a multi-billion-dollar market within the medical diagnostics industry.	Causeway Sensors	UG	3 PDRA yrs. and 3 PhD yrs.
Sustainable manufacturing	14	Optimising Laser welding process parameters for Polypropylene (PP) bottles.	To investigate Polypropylene (PP) characterisation techniques for developing chemometric models that can help infer/predict optimum laser welding processes parameters that can reduce PP bonding cycle times and eliminate overall production scrape/failure rates.	Abbott Diagnostics manufacturing facility in Sligo includes an automated bottling process line. Polypropylene containers (100ml) are feed onto a production line that fills the containers with a formulation solution that are then sealed with a PP cap that is laser welded on to the top of the bottle container. Every new batch of PP containers and caps that are processed on this line will have slight inconsistencies with respect to molecular structure due to marginal variations (pellet moisture, amount of dye used for IR absorption etc.) experienced during third party manufacturing process. These molecular	Abbott	ITS	2.5 PDRA yrs. and 3 PhD yrs.

Table 3.1: Overview of the Proposed R&I Projects							
	Project No.	**Title**	**Aim**	**Driver**	**Industrial Partner**	**R&I Partners**	**Resources**
				variations are not well quantified or understood with respect to the thermal dynamics experienced by PP bottle components during the laser welding process, consequently resulting in a possible adverse impact on welding cycle times, bonding quality and ultimately production scrap rates.			
Sustainable manufacturing	15	Minimising energy utilisation for batch production through multivariate scheduling optimisation.	To determine if manufacturing energy plant capacity can be quantified and correlated to optimal schedule planning for batch production through the use of multivariate techniques and predictive statistical models	GSK currently operate a high-volume batch production process facility that utilises a number of large mixing chambers for manufacturing a wide range of emulsion products. The factory utilises a boiler plant comprising a heat exchanger and chiller system for servicing the heating and cooling requirements that are necessary to maintain set temperature control of the formulation solution for up to 6 mixing chambers that can be in operation at the same time. Each product formulation requires different temperature range controls, which at times can exact significant demand on energy plant capacity to service divergent temperature requirements of multiple mixing chambers operating in parallel.	GSK Stiefel	ITS	2.5 PDRA yrs. and 3 PhD yrs.

The project partners suggest that the capabilities of the institutions are complementary. For example:

- Project 2 requires both a knowledge of polymer materials and processing (UU) as well as process control (ITS). The partners note that changes in process parameters such as cooling rates may significantly influence the structure and properties of finished parts. For project 2, UU will determine how process influences structure and properties and identify the key influencing process parameters and ITS will determine the process control necessary to ensure a robust process and product of consistent dimension and properties.
- Project 10 requires and expert knowledge in polymer materials and processing (UU) as well as machine development and control systems (LyIT). It would not be possible for LyIT to design and build this machine without knowledge of the polymer materials to be processed and their particular processing requirements (e.g. heating, cooling, shear rates etc.).

3.2.3 Project Governance & Management

As Lead Partner, C-I has established the following governance structure to ensure the effective oversight and successful implementation of the NWCAM project.

Project Board	A Project Board comprising representatives from academic and industrial partners in addition to representatives from the SEUPB; Donegal County Council and Derry City and Strabane District Council; and other regional competence centres as required has been established.
Lead Partner	As Lead Partner, the C-I Senior Management Team is ultimately responsible for the effective implementation and administration of the Project.
Principal Investigator	Dr Alistair McIlhagger is the Principal Investigator for the Project. He is responsible for managing the four individual Thematic Research Area programmes and ensuring effective integration of the same.
Thematic Leads	Individual Academic Partners will take responsibility for leading each of the four Advanced Manufacturing Thematic Research Areas. Each of the Thematic Leads is required to provide quarterly reports against an agreed programme of activity; designed to ensure that the Project's result and output indicators are delivered within the required timeframe. An overview of the related responsibilities of each Academic Partners is outlined below.
	Ulster University *(Advanced Polymers)* — Under the direction of Dr Alistair McIlhagger, Ulster University will be responsible for managing six R&I projects with three industrial partners (Armstrong Medical; Laser Prototypes Europe; and Randox Laboratories). Input will also be provided from the Institute of Technology Sligo.
	Ulster University *(Additive Manufacturing)* — Under the direction of Dr Justin Quinn, Ulster University will be responsible for managing three R&I projects with two industrial partners (Laser Prototypes Europe; and Sphere Global). **Note:** Letterkenny Institute of Technology will lead the remaining project within this Thematic Area.
	University of Glasgow *(Nano-Manufacturing)* — Under the direction of Professor Steve Beaumont, the University of Glasgow will be responsible for managing three R&I projects with three industrial partners (Nuprint; Sphere Global; and Randox Laboratories). Input will also be provided from the Institute of Technology Sligo.
	Institute of Technology *(Sustainable Manufacturing)* — Under the direction of Dr David Tormey, the Institute of Technology Sligo will be responsible for managing two R&I projects with two industrial partners (Abbott; and GSK Stiefel). Input will also be provided from Ulster University.
Project Management Team	C-I will establish and oversee a core Project Management Team to effectively oversee the day-to-day operations of the Project. This team will comprise a Project Manager; two Innovation Brokers; Administration Officer and part-time Finance Officer. The Project Manager will coordinate quarterly meetings of all partners for the duration of the Project.

As Lead Partner, C-I has assembled a dedicated Project Team to oversee the operational management and administration of the NWCAM project. This team is led by a Project Manager. It also comprises two Innovation Brokers; an Administration Officer and part-time Finance Officer. The roles and responsibilities associated with these positions are outlined below:

1 Full-time Project Manager	The Project Manager supports the PI (UU) in the management and effective integration of the four selected Advanced Manufacturing thematic research areas. The Project Manager also oversees the coordination and administration of all aspects of NWCAM including planning, organising, staffing, leading, and controlling programme activities. They are responsible for ensuring that all project milestones are achieved within the required timeframes and for the coordination and presentation of related reports to the Project Board and the SEUPB. This is a new position.
2 Full-time Innovation Brokers	C-I has appointed two Innovation Brokers to be responsible for managing effective relationships with the eight industrial partners engaged within the Project. The role of the Innovation Brokers is as follows: **To manage and take responsibility for commercialising the CAM research and IP portfolio** to maximise regional economic impact. This includes developing strategic partnerships with industry, nationally and internationally, the facilitation of successful technology transfer and working with relevant agencies to promote foreign direct investment. It also involves generating significant new revenues derived from commercial exploitation to ensure the sustainability and growth of the Centre. This involves monitoring the achievement of agreed activities and milestones established to ensure that the Project results in the desired level of commercial benefit for the individual industry partners and the regional economy generally. Accordingly, the Innovation Brokers are responsible for developing an Innovation Management Plan for each of the eight industrial partners. These individuals report directly to the Project Manager. These are new positions.
1 Full-time Administrator	The Project Administrator reports to the Project Manager and is responsible for coordinating all the administrative elements of the Project. This will include administering all Partner and Project Board meetings and assisting with the preparation of all the requisite progress reports. This is a new position.
1 Part-Time Finance Manager	The Part-Time Finance Manager will be responsible for administering all financial elements of the Project and preparing related reports for the Project Board and the SEUPB. This is an existing position within C-I.

Organisations involved in the Small Grant Award process as an independent assessment panel members include:

- Derry City and Strabane District Council
- Invest NI
- Ulster University
- Highlands and Islands
- Interface
- University College Dublin – iForm centre
- Scottish Enterprise
- Enterprise Ireland

Eight work plans have been developed.

Table 3.2: Summary of NWCAM Project Work Plans (Per Progress Reports)
1. Management
2. Advanced Polymers
3. Additive Manufacture
4. Nano Manufacturing
5. Sustainable Manufacturing
6. Small Grant Awards
7. Management and Innovation brokerage
8. Communication

3.3 Project Budget

The NWCAM project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €8,518,406.33 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,779,853.06, as summarised in the tables below:

Table 3.3: Anticipated Project Costs	
Summary Budget	**Total Project Costs (€)**
Staff Costs	4,616,795.81
Office and Administration Costs	1,715,377.88
External Expertise and Services	1,725,255.10
Travel and Accommodation Costs	111,517.03
Equipment Costs	610,907.24
Total	**8,779,853.06**

Table 3.4: Anticipated Project Funding	
Funding Sources	**Total Value (€) (Public)**
Cash Contribution (Partner Supplied/other grant)	261,446.72
Government Match Funding	1,055,531.25
ERDF	7,462,875.08
Total Grant Funding	**8,518,406.33**
Total Project Costs	**8,779,853.06**
Intervention rate (% ERDF)	85%

3.4 Anticipated Project Objectives, Outputs and Results

3.4.1 Objectives

The project's stated objectives are as follows:

Table 3.5: Project's Objectives	
Specific (Objective)	**Measure**
1. Increase the level of cross border collaboration across the Region in the area of applied Advanced Manufacturing R&I.	4 research institutions collaboration across NI; Ireland; and Western Scotland **(CO42 and C024)**.
2. Increase the number of regional Health and Life Sciences (including supply chain) sector companies engaged in commercially driven cross border Advanced Manufacturing R&I.	8 regional Health and Life Sciences (and supply chain) companies collaborating with a cross border R&I cluster incorporating 98.5 years' worth of PhD input from 48 PhD level researchers **(CO41, C026, C04, C02 and C01)**.
3. Further develop the regional economy through the development of new products and/or processes (TRLs 2 – 6) within the Life and Health Sciences Sector; developed as a result of the application of Advanced Manufacturing technologies.	15 individual R&I projects across 8 industrial partners **(CO41)**[37].
4. Increase the awareness of the potential of Advanced Manufacturing as an enabling technology within the Life and Health Sciences Sector and others key to the Region's current and future economic success.	30 peer-reviewed journal articles with cross border authorship illustrating the commercially beneficial application of Advanced Manufacturing technologies within the Health and Life Sciences Sector **(Interreg VA 1.1 Result Indicator)**.

[37] Suggested to create 15 New Health and Life Sciences products (TRL 2 – 6) and or processes.

3.4.2 Outputs

Per the Letter of Offer (dated 21st June 2017), the anticipated (approved) NWCAM project outputs are as follows:

Table 3.6: Anticipated Project Output Targets

Output Code	Name of Output	Programme target	NWCAM target		Notes
CO01	Number of enterprises receiving support	20		8	The following businesses were proposed by the project partners: • Sphere Global • Nuprint • Randox • Armstrong Medical • Bemis Healthcare packaging • Laser Prototypes Europe • Abbot • Stiefel GSK As noted later, the cohort of businesses receiving support through the Programme ultimately changed from those anticipated at the outset.
CO02	Number of enterprises receiving grants	10		2	It is anticipated that the Project Board will manage a number of mini-calls for applications for small grants for additional consumables as required to support /enhance individual R&I projects.
CO04	Enterprises receiving non-financial support	20		8	As per CO01
CO24	Number of new researchers in supported entities		T1.3.1	29.50	98.5 FTE researcher years, as follows: • 11 full-time Post-Doctorate Research Associates (39 researcher years) • 13 full-time PhD students (40 researcher years) • 16 Principal Investigators/Co-Investigators/Innovation Brokers (19.5 researcher years) NB projected to include: 24 new researchers in supported entities.
			T2.3.1	25.50	
			T3.3.1	21.50	
			T4.2.1	13.00	
			T6.1.1	9.00	
		514		**98.5**	
CO26	Number of enterprises cooperating with research institutions.	10		8	As per CO01
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects.	10		8	As per CO01
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects.	5		4	• University of Ulster • Institute of Technology Sligo • Letterkenny Institute of Technology • University of Glasgow

NWCAM provided the following overview of the allocation of Output Indicators amongst the Project Partners for monitoring purposes:

Table 3.7: Anticipated Output Indicators by Project Partner

Output Code	Name of Output	Catalyst Inc	Ulster University	University of Glasgow	Institute of Technology Sligo	Letterkenny Institute of Technology
CO01	Number of enterprises receiving support	8	39.5 yrs	21.5 yrs	22 yrs	7.5 yrs
CO02	Number of enterprises receiving grants	Co-ordinator (4)	1	1	1	1
CO04	Enterprises receiving non-financial support	Co-ordinator (8)	3	2	2	1
CO24	Number of new researchers in supported entities	2	-	-	-	-
CO26	Number of enterprises cooperating with research institutions.	Co-ordinator (8)	3	2	2	1
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects.	Co-ordinator (8)	3	2	2	1
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects.	Co-ordinator (8)	3	2	2	1

The project partners also provided the following breakdown of the projected 98.5 PhD (or equivalent) research years.

Table 3.8: Breakdown of PhD Research Years

	PhDs		PDRA		CI/PI/IB	
	No. of Staff	No. of Years	No. of Staff	No. of Years	No. of Staff	No. of Years
Catalyst Inc	0	0	0	0	2	8
UU	8	24	6	20	7	6
LyIT	0	0	1	5	1	1
Glasgow	3	9	3	10	3	2.5
ITS	2	6	1	5	3	2
Total	**13**	**39**	**11**	**40**	**16**	**19.5**

3.4.3 Results

It is anticipated that the NWCAM project will contribute to the target number of 75 annual peer-reviewed journal and conference publications within the Health and Life Sciences Sector through the development of 30 publications with cross border-authorship.

Table 3.9: Anticipated Result Indicators

Interreg VA 1.1 Output Indicators	**Anticipated Contribution of NWCAM**
75 peer-reviewed journal and conference publications within the "Health and Life Sciences' and 'Renewable Energy' sectors with cross border-authorship and with the potential to create economic impact'	**30** peer-reviewed journal and conference publications within the "Health and Life Sciences' and 'Renewable Energy' sectors with cross border-authorship and with the potential to create economic impact' ***(40%)***

The anticipated breakdown of these publications across the proposed Advanced Manufacturing Thematic Research Areas is as follows:

Table 3.10: Anticipated Publications across the proposed Thematic Research Areas

Thematic Research Area	**Cross Border Research Partners**	**Target Number of Peer-reviewed Journal and Conference Papers with Cross Border-Authorship**
Sustainable Manufacturing	Ulster University; and Sligo Institute of Technology	8
Advanced Polymer Products	Ulster University; and Sligo Institute of Technology	8
Additive Manufacturing	Ulster University; and Letterkenny Institute of Technology	6
Nano Manufacturing	University of Glasgow; and Sligo Institute of Technology	8
Total		**30**

The project partners anticipate that the publications will be in the top-ranked journals within the Advanced Manufacturing discipline including Applied Energy Impact (Factor 5.6), Composites Science and Technology (IF=3.56); Macromolecules (IF=5.8); RSC Advances (IF=3.84); Polymer Engineering and Science (IF=1.243); and Journal of Applied Polymer Science (IF=1.395).

With regard to Open Access Journals, the Project Partners will adhere to UU's Open Access Policy. This supports the Open Access of research as part of its mission to be recognised globally for the quality of its research and welcomes moves by Research Councils and other external funding bodies to promote unrestricted access to the published output from the research they fund.

The Policy requires all staff to pursue the Green OA Route and self-archive their accepted articles and make these OA via the Ulster Institutional Repository (UIR). UU's Research Data Management Policy requires all staff to archive and make Open Access the underlying data associated with their research in the University's Data Repository to meet the requirements of external funders. The project partners will be encouraged to pursue the Gold OA Route were financially possible.

3.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the NWCAM project's key achievements (as of July 2019) and the extent to which the NWCAM project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

3.5.1 *Key Achievements (to July 2019)*

The NWCAM project partners report the following key achievements (as of July 2019):

- A NWCAM full partner project update event was held during April 2019 – academics and industrial partners met to provide an overview of individual projects; presentations by Catalyst, Nuprint, axial3D and Leckey;
- Armstrong Medical are working towards patent pending for their R&D with UU;
- All 13 PhD researchers and 13 postdocs (full-time positions) are in position;
- IT Sligo – The closure of GSK's Sligo plant was announced during August 2018. Academics in IT Sligo and GSK staff in Sligo are working collaboratively to scope and identify the sustainability of the project post-funding applying the research completed so far in an alternative plant. Discussions have been ongoing and potential for re-location of the project to GSK in Irvine is considered possible, work continues in this area.
- Nuprint and the University of Glasgow collaborated (co-sponsored by Catalyst) in representation at the FLEPS IEEE conference during July 19. Nuprint MD Gavin Killeen was a member of the panel session on 'commercialisation opportunities for flexible electronics and printed sensors' chaired by lead academic on Nano Manufacturing, Professor Steve Beaumont. The conference was attended by approx. 150 delegates.
- Small Grant Award – update of the process was detailed as follows:

  - An independent assessment panel was designed to offer a representation of key stakeholders across the INTERREG region;
  - A Terms of Reference developed and circulated;
  - Non-disclosure agreements were developed and accepted by the assessment panel;
  - 4 eligible applications received and independently assessed and all 4 applications were deemed worthy of support; and
  - Letters of offer were circulated to the potential awardees for consideration and acceptance of the conditions of the award.

- axial3D founder, Dan Crawford, participated in scaling programme through Catalyst to develop his leadership skills and business development potential through a group visit and study in MIT Boston.

The project partners have provided the following details of 15 individual projects that have been supported.

Table 3.11: Overview of NWCAM Projects					
	Project No.	**Title**	**Industrial Partner**	**R&I Partners**	**Progress (at July 2019)**
Advanced Polymers	1	Development of insulated medical tubing with controlled gas barrier properties	Armstrong Medical	UU (Jordanstown)	Partnering with NIBEC, Ulster University (UU), the project aims to improve existing polymeric material used in critical care and life support breathing tubes and in particular addresses the issue of condensation built up in said tubes delivering gas to patients. The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A report detailing company induction and consensus approach to the project, including assessing current tubing design, materials, processing and performance as well as current user-product performance information. • A report detailing the literature review pertaining to project with findings. • An initial product prototype report. • An assessment of the patent landscape has been conducted via Ulster's technology transfer office, Innovation and Impact **and an invention disclosure relating to this project is currently being assessed for patentability with an aim of filing a UK patent application in the next 3-4 months**.
Advanced Polymers	2	Improving the processability and performance of polypropylene parts	Armstrong Medical	UU (Jordanstown)	The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • The researchers have had several visits to the industrial partner and have completed trials on injection moulding. • A comprehensive literature review was completed for Advanced Polymers pertaining to Armstrong Medical's medical tubing of polypropylene material. • A first-year report was delivered. The outcomes and areas of progress were shared with all the academic partners to be able to identify potential joint authorship papers.
Advanced Polymers	3	Development of high performance PEEK composite	Denroy	UU (Jordanstown	Denroy is partnered with Ulster University to develop new materials that are potentially recyclable and also experimenting to improve the performance of current materials used in their products. Key deliverables reported as being achieved included:

Table 3.11: Overview of NWCAM Projects

	Project No.	Title	Industrial Partner	R&I Partners	Progress (at July 2019)
					• A number of meetings with technical staff and academic researchers have taken place with Denroy Plastics, albeit the PhD Appointment working with Denroy did not take up appointment until 19th Nov 2018. • Literature review, materials investigations and testing at UU Jordanstown and NIACE are all being progressed. Reviews of PEEK and expanded graphite materials have been conducted on the technical properties; sample testing and results have been reviewed and results have been shared. Discussions are ongoing for Denroy to provide a testing rig for environmental stress testing.
Advanced Polymers	4	Assessment of recyclability of multifunctional PEEK composites	Denroy	UU (Jordanstown)	The project was proceeding according to its work plan. Key deliverables reported as being achieved included: • A number of meetings with technical staff and academic researchers have taken place with Denroy Plastics, albeit the PhD Appointment working with Denroy did not take up appointment until 19th Nov 2018.
Advanced Polymers	5	Development of advanced materials for additive manufacturing of medical devices and components	Laser Prototypes Europe (LPE)	UU (Jordanstown)	The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A report detailing company induction and consensus approach to the project; • A report detailing the literature review pertaining to project with findings; • A report detailing progress made in the first year of the project.
		Integration of Injection Moulded Plasmonic Nanostructures into a Biosensor Device (Project A)	Causeway Sensors	UU (Jordanstown)	See Project 13 for details on project progress.
Advanced Polymers	6	Development and characterisation of additive manufacturing polymers for use in advancing surgical practice.	axial3D	UU (Jordanstown)	Ulster University and axial3D are collaborating to develop polymer materials that can be used to advance surgical practices, in particular, medical 3D printable bioimplants at Point of Care (PoC) in a hospital setting. Due to the change of industrial partner on the work plan the initial company visit and induction documents had not been completed with axial3D in December 2018. The PhD student resource commenced in October 2018. The postdoc position started in mid-February 2019.

Table 3.11: Overview of NWCAM Projects					
	Project No.	**Title**	**Industrial Partner**	**R&I Partners**	**Progress (at July 2019)**
					Progress on the project so far is focused on literature reviews, designing the project definition, associated project work plans and milestones
Additive Manufacturing	7	Optimisation of the laser sintering of metal parts for medical products	Laser Prototypes Europe (LPE)	UU (Magee)	LPE is working with Ulster University to test materials and explore additive manufacturing builds using titanium powders. The investigations are to examine how to increase 3D build times, identify efficiencies and investigate new materials that could be applied to the medical market and further afield. The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A report following the visit to industrial partner including project plan. • A report on the review of literature salient to the project. • Testing and development of the experimental regime in collaboration with LPE were ongoing. Experimental plan to be performed, evaluating the z-direction variation within titanium components and to analyse powder throughout a recycling regime. • A conference paper has been submitted.
Additive Manufacturing	8	Development of process simulation models for metal laser sintering	Laser Prototypes Europe (LPE)	UU (Magee)	The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A report following the visit to industrial partner including project plan. • A report on the review of literature salient to the project. • Work for a Simulation requirements report - with LPE is ongoing. The project had performed micro-CT scans at UU to become familiar with the instrument and data processing; participated in the tensile testing of the LPE metal samples at UU. Modelling work was therefore progressing.
Additive Manufacturing	9	Development of process simulation models for laser sintering and fused deposition modelling of polymers	Laser Prototypes Europe (LPE)	UU (Magee)	The project was reported as proceeding according to the work plan. However, it was also reported that LPE had been initially anticipated to be the industrial partner however there had been conversations to indicate a potential change of industrial partner. The postdoc had explored a number of potential replacement partners and had visited axial3D to become familiar with their goals and plans and problems in using additive manufacturing technology in the production of medical implants and devices.
Additive Manufacturing	10	Development of a new additive manufacturing machine to enable the use	Leckey	LyIT and UU (Magee)	Leckey is partnered with Letterkenny Institute of Technology and the team at Magee campus of Ulster University to develop a novel adjustable seating cushion with integrated pressure matt sensors using additive manufacturing techniques,

Table 3.11: Overview of NWCAM Projects

	Project No.	Title	Industrial Partner	R&I Partners	Progress (at July 2019)
		of engineering polymers and larger part builds			investigations are ongoing in terms of literature reviews for UU and LyIT regarding materials investigation and sensor technologies that could be used within the medical markets that are cost-effective and technologies that can be scaled relatively easily using a variety of manufacturing techniques.
Nano-manufacturing	11	Printing of Electronic Layers and Devices on Flexible substrates	Nuprint	UG	Nuprint is working with the University of Glasgow investigating flexible sensors and new printing material technologies with new market opportunities applicable to the medical, food and beverage markets, for example, having the ability to use sensor temperature technologies. The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A report following initial interaction with the industrial partner. • A literature review was completed on articles salient to the project. • Prof Ravinder and the research team visited Nuprint 22nd July 19 for a factory tour to provide the research team with a better understanding of the business and product range to be able to apply this to their research.
Nano-manufacturing	12	Smart printed RFID Sensor Tags for Health Monitoring	Nuprint	UG	
Nano-manufacturing	13	Integration of Injection Moulded Plasmonic Nanostructures into a Biosensor Device (Project B)	Causeway Sensors	UG	Causeway sensors are working with University of Glasgow (UG) to design and produce injection moulded plasmonic nanostructure arrays for integration into a plasmonic biosensor device for rapid biological sensing of animal and human disease pathogens such as in sepsis or tuberculosis. The overall aim for Causeway Sensors is to create a 'point of care' microfluidic diagnostic platform which is rapid, highly sensitive, simplistic to use with low sample consumption. The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • The PDRA visited Causeway Sensors in Belfast on 4 October 2018. This culminated in the development of an action plan to guide practical activities over the following three months. • A literature review was completed on articles salient to the project. • The project is progressing well and UG researchers have provided a number of arrays which are currently being tested by the Causeway team.
Sustainable manufacturing	14	Optimising Laser welding process parameters for	Abbott	ITS	Abbot alongside IT Sligo is investigating a manufacturing setting of automated bottle fill line (used for clinical diagnostic assays) primarily focused on increasing throughput and productivity and minimising defects in the laser welding process of the bottles.

Table 3.11: Overview of NWCAM Projects

	Project No.	Title	Industrial Partner	R&I Partners	Progress (at July 2019)
		Polypropylene (PP) bottles			Research studies so far have been to gain an understanding of weld defects, results have identified a number of key weld zones where most defects arise. Future work will focus on the characterisation of the material structure and melt flow of the polymer The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A company visit report. • Review of literature salient to the project.
Sustainable manufacturing	15	Minimising energy utilisation for batch production through multivariate scheduling optimisation.	GSK Stiefel	ITS	IT Sligo and GSK are working on understanding the energy usage within a manufacturing plant and changing the scheduling of work to reduce costs and improve business efficiencies. The project was proceeding according to the work plan. Key deliverables reported as being achieved included: • A company visit report; • A conference paper; GSK Sligo based plant is closing, the teams have been scoping a potential project move to GSK in Irvine, work has been ongoing to understand the Irvine energy profile and if/how the project could be applied to an alternative plant.

The NWCAM project partners also cite the project's key project achievements (as of December 2018[38]) as being:

Table 3.12: Key Achievements

Period	Dates	Key Achievements
1	1st April 2017 - 30th June 2017	• All academic partners were involved in agreeing on numerous deliverables across each of the 15 R&I work plans as well as agreeing forecast expenditure profiles; • Due to governance restrictions within their respective organisations, none of the partners on the NWCAM project was permitted to commence the staff recruitment process until the final letter of offer was delivered by SEUPB, delaying recruitment by 3 months.
2	1st July 2017 – 30th September 2017	• A successful NWCAM launch event was held - The Principal Investigator outlined the research being undertaken, as well as industrial partner presentations to outline the importance and value of the research and the positive impact this will have on their business in terms of business development and innovation. • Research units had drafted recruitment paperwork and there was a varying degree of progress of recruitment of PhD students and the appropriate level of research assistants to undertake the research work.
3	1st October 2017 – 31st December 2017	• Key project posts were filled by the Lead Partner including Project Manager, Project Administrator, whilst the two Innovation Brokers posts were offered. • Recruitment of key research staff continued to progress within academic institutions. However, some organisations were experiencing long delays due to under-resourced HR departments and some misunderstanding about opportunity advertisement for staff undergoing re-evaluation. • The Lead partner designed, prepared and agreed with partners a NWCAM Project Charter, consolidating the Project Board, drafting the operational communications plan and securing governance meetings for the forthcoming year.
4	1st January 2018 – 31st March 2018	• The two Innovation Brokers commenced their roles; • Likewise, the research partners continued to appoint suitability skilled and experienced post-doctoral staff and recruited PhD students to undertake the 15 R&I work packages. According to the project partners, ensuring the suitability of candidates was paramount which resulted in a longer recruitment process than initially anticipated. • Key deliverables within the project had been achieved including literature reviews and company visit reports (an accumulation of a number of visits, meetings, discussions and reviews of the industrial problem in order to understand the company, the fit with the research capability and designing the research project in a collaborative approach).
5	1st April 2018 - 30th June 2018	• The project experienced a successful industrial partner replacement from Sphere Global to bring in Denroy and Leckey with projects within Health and Life Sciences. The approval for the consortium was granted by SEUPB steering committee and the Innovation Brokers were able to secure Partnership Agreements to establish good governance with the businesses. • Conference attendance saw the presentation of early emerging research of NWCAM; • The Innovation Brokers spent time building relationships with the research staff and gaining a technical understanding of the projects, which was anticipated to help them to represent NWCAM at events and networking opportunities to increase awareness of the project.
6	1st July 2018 – 30th September 2018	• Industrial partner composition had to be reviewed when Randox withdrew based on IP ownership terms; • The Innovation Brokers identified two partnerships with innovative companies: axial3D and Causeway sensors. A proposition paper was developed and accepted by SEUPB.

[38] Please note that the key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing.

Table 3.12: Key Achievements		
Period	**Dates**	**Key Achievements**
		• A further proposition paper for change regarding Nanomanufacturing was submitted during August 2018 for an additional project with Nuprint and engaging Thermofisher (a decision was pending).
7	1st October 2018 – 31st December 2018	• A successful full consortium partners meeting was held introducing industrial partners to academic staff; PhD students showcased their projects and participated in the networking of all partners and discussed their individual projects. • The marketing videos of NWCAM partners' were played to show the resource invested in communicating the ongoing projects. • The Project Board met 30th October 2018 where the retirement of Project Board Chair, CEO of Catalyst Inc was announced and it was advised that the new chair, Steve Orr will be taking over the role. The Principal Investigator of NWCAM also announced to partners that she was stepping down from her role at Ulster University, with the role taken over by Dr Alistair McIlhagger. • Communication and marketing activity was impactful with a press release in NI, Business Eye magazine and a Banner advert and IT Sligo article in the Irish Independent newspaper. The third e-zine released on 19th Dec 2018. • Outreach and engagement with relevant stakeholders have been positive within this quarter with a number of events and conferences attended including Additive Manufacturing event at NI Tech Centre, Innovate UK funding events and Life and Health Science related conferences. • Ongoing engagement was maintained with industrial partners, with each of the projects operating at different stages of development such as Armstrong Medical continuing to move towards generating new discoveries and exploring IP protection, Causeway Sensors was beginning design of the multi-well container for early prototype suggestions.

3.5.2 Progress towards the Project's Output Indicators

Table 3.13 (overleaf) provides a high-level summary of the progress that has been made by the NWCAM project towards its Output Indicators.

Table 3.13: Progress towards Output Targets

Output Code	Name of Output	Programme target		NWCAM target	Progress as of July 2019	Variance against project target	Commentary
CO01	Number of enterprises receiving support	20		8	9	+13%	**Proceeding according to the project work plan.** As noted, 9 businesses are currently engaged across 15 research projects. The businesses include Abbott, Armstrong Medical, Laser Prototypes Europe, GSK Stiefel, Leckey, Nuprint; Denroy Plastics Ltd; axial 3D and Causeway Sensors
CO02	Number of enterprises receiving grants	10		2	0	-100%	**Proceeding according to the project work plan.** An open call for applications was issued to fund industrial projects up to a value of c.€50k. 4 applications were received and were assessed by an independent panel consisting of Invest NI, Enterprise Ireland, Interface, Highlands and Islands Enterprise, Ulster University and Derry City and Strabane District Council (DCSDC). All four applications were all deemed to be eligible, passing the minimum assessment thresholds that were established. LoOs have been circulated to all 4 applicants for consideration and acceptance of the conditions of the award.
CO04	Enterprises receiving non-financial support	20		8	9	+13%	**Proceeding according to the project work plan.** As above 9 businesses have received non-financial support through the 15 research projects.
CO24	Number of new researchers in supported entities		T1.3.1	29.50	5.42	-82%	**Proceeding according to the project work plan.** Research years are anticipated to increase as the research projects continue to be taken forward. Delays in the recruitment of PhD students and changes to the student profile has hindered the progress towards this target to date.
			T2.3.1	25.50	8.10	-68%	
			T3.3.1	21.50	3.10	-86%	
			T4.2.1	13.00	4.29	-67%	
			T6.1.1	9.00	2.71	-70%	
		514		**98.5**	**23.62**	**-76%**	
CO26	Number of enterprises cooperating with research institutions.	10		8	9	+13%	**Proceeding according to the project work plan.** As above, 9 businesses are currently engaged across 15 research projects.
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects.	10		8	9	+13%	
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects.	5		4	4	-	**Proceeding according to the project work plan.** Four academic institutions (UU, IT Sligo, LyIT and UG) are actively involved in the delivery of the project's research projects.

In summary, the NWCAM project is progressing towards its project work plan and is on progress to achieve each of its respective output indictors.

3.5.3 *Target Groups Reached*

Table 3.14 provides an overview of the target groups researched as a result of the Project's activity to date.

Table 3.14: Target Groups Reached			
Target Groups	**Target Value**	**Target Groups Reached**	**Notes**
Higher education and research	-	4	The four Academic partners are continuing to actively support and co-ordinate research staff and students to carry out the activities associated with their work plans and address the needs of the outputs of the project.
Enterprise, excluding SMEs	-	3	The Innovation Brokers were actively reinforcing enterprise engagement with a variety of meetings, conference calls and email contact.
SMEs	-	6	Six SMEs were partnering on NWCAM, including Leckey, Armstrong Medical, Laser Prototypes Europe (LPE), Nuprint, Causeway Sensors and axial3D. Each of the SMEs had accepted the Partnership Agreement and signed the Annex 10 to agree to the terms of research ownership.

3.5.4 *Progress towards the Project's Result Indicator Targets*

Per Table 3.15, it is anticipated that the NWCAM Project would contribute 30 peer-reviewed journal and conference publications with cross-border authorship.

Table 3.15: Progress towards Result Indicator Target		
	NWCAM Target	**Progress (at July 2018)**
Peer-reviewed journal articles with cross border authorship	30	0

To date, the project has not finalised any peer-reviewed journal and conference publications with cross-border authorship, albeit the Project Partnership notes that, at the time of writing, 2 are currently being progressed/prepared. Project Partners also indicate that 10 publications have been created on a single jurisdiction basis.

3.5.5 *Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives*

The Project Partners advise that the project has encountered a number of issues in the delivery of the NWCAM project to date. Whilst noting that some of these issues have combined to slow progress towards elements of the output indicators (e.g. the number of PhD years), the Project Partners do not anticipate that these will ultimately have an adverse impact on the longer-term achievement of the Project's Output and Result indicators and the Priority's Specific Objectives.

Specific issues identified by the Project Partners include:

- **IP issues impacting on businesses engagement on the project** - As noted previously, it was anticipated that Randox Laboratories Ltd and Bemis Healthcare Packaging would receive support through the NWCAM project. However, due to the fact that the ownership of any foreground IP emanating from the research would ultimately reside with the academic institutions, both businesses decided to withdraw from the project. Indeed, the lead Project Partner indicated that this IP issue also prevented a further business (Thermo Fisher, based in Scotland), who could have provided substantive input into one of the research projects, from engaging on the project[39];

[39] A further prospective partner (Sphere Global) went into administration

- **Delays in the recruitment of research staff -** Consultation with the NWCAM project partners indicates that there were considerable delays in recruiting the project's PhD student cohort and post-doctoral research positions. The Project partners note that there was a general lack of appetite from domestic research staff applicants and, of those that did apply, a considerable number were deemed not to be of the requisite quality which the project required (e.g. in terms of their skill sets and experience of working with industry). Consequently, the Project Partners sought applications from potential international PhD students (using the 'Find a PhD' online platform). However, there were subsequent delays in these students working on the project due to the necessity to secure visas. The Project Partners note however that this did not result in a lack of individual research project progress on the basis that preliminary work had to be undertaken by the Principal Investigators (PIs) to define the projects;

- **Changes to the research team profile during the delivery of the research projects** – The Project Partners note that there has been a number of changes to the profile of the project's research team during the initial delivery period. Examples of changes include a change to the lead PI within UU (from Professor Eileen Harkin-Jones to Dr Alistair McIlhagger), a PhD student going on maternity leave, Post-doctoral research staff returning to their home country or moving to different post within the University or leaving the University.

  Although the project partners report that replacements and/or alternative arrangements have been agreed and negotiated; they note that it is important to maintain the industrial partners' focus and progression of the project; and

- **EU and University Procurement requirements hindering the progression of research -** According to the NWCAM project partners, the progression of research has been hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed to conduct research. The Project Partners notes that whilst activities need to be directed to other specific areas of research within the project, they require specific equipment to achieve related deliverables (e.g. delays in the installation of the Additive WP10 robotic arm has resulted in delays in completing initial test reports).

Conversely, the project partners note that a positive external factor is C-I's involvement with the City Deal which has served to focus stakeholders on the potential sustainability of the activities within their projects beyond the NWCAM project period.

3.6 Best Practice and Learning

The NWCAM project partners report that the project has resulted in the following areas of best practice and learning:

- **The utilisation of wider advanced manufacturing and composites facilities to support project delivery** – It is noted by the Project Partners that IT Sligo and UU have jointly utilised that NIACE facility to undertake joint testing using the facility's specialist equipment;

- **The utilisation of Innovation Brokers to explore commercialisation opportunities –** The project's Innovation Brokers role in the project is to develop an understanding of the nature of the research being undertaken and its potential industrial application in order to identify potential routes to market. Thus, the structure of NWCAM has a built-in specific commercialisation focus to maximise the potential impact of the project;

- **The honest broker role played by C-I and its knowledge of the wider industrial landscape -** The 'honest broker' role of the lead partner seeks to ensure equal management support to all academic and industrial partners. The focus of Catalyst as an entrepreneurial support hub offers, in its view, a unique partnering of the organisations' strategic goal of economic development of the region to the outputs identified by the project;

Linked to this, the use of Catalyst's understanding of the business landscape has facilitated industrial partner changes. The networks within the organisation have allowed for potential partners to be identified and scoped to find the best 'fit' with researchers and organisations that could benefit from their participation in the project. The partners consider that this will ensure the greatest impact of the R&D activity;

- **Rotation of the project's communication and outreach activities** - Communication and outreach activities (e.g. academic partner meetings, press releases) are rotated amongst the partners' jurisdictions to build equity, a joint sense of ownership amongst the NWCAM partners (thereby also ensuring that the project is not perceived to be Belfast-centric), as well as break-down any perceived barriers to collaboration (e.g. that may exist due to the presence of a border);

- **The establishment of an informal 'Project Managers' Group'** has facilitated open discussion in relation to INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allows for cross-over of learning and insights that have been gained by each project manager;

- **Development of a project-level MIS** - A research years' tracker was developed and implemented for the research staff to ensure that the output of the project is closely monitored and achieved each quarter.

- **Hosting of research outputs to promote knowledge transfer** - In terms of learning, journals and international conference papers are hosted on an open website via Catalyst on the NWCAM home page to promote open-source access and knowledge sharing throughout the Regions' Advanced manufacturing and/or L&HS sectors; and

- **Community building** – There has been positive engagement within the wider research community, including being able to signpost stakeholders to other INTERREG expertise, topical events, networking opportunities etc.

3.7 Synergies between Projects funded

Other than engaging in a number of informal meetings with the other INTERREG VA project managers, the Project Partners indicate that there have been no further synergies between the funded projects.

3.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the NWCAM project's collaborative and partnership working including:

- The effectiveness and added value of the NWCAM project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

According to the NWCAM project partners, there have been considerable benefits to developing and delivering the Project on a cross border basis, with key highlights identified as including:

- LyIT's and UU's collaboration, where the resourcing is split between the two organisations, forging close collaboration for shared project delivery;
- IT Sligo and UU using NIACE's facilities to run joint testing. IT Sligo visiting facilities and conducting material testing using UU equipment; and
- Glasgow using IT Sligo laser welding equipment.

Other identified benefits include:

- The implementation of the Project on a cross border basis has facilitated industry partner exposure to additional research facilities and expertise not available on a single jurisdiction basis which they envisage will have a positive impact on the individual company and the wider economy;
- The deployment of 24 new skilled commercially aware researchers across the Region;
- The facilitation of knowledge exchange and facility sharing among academics from across the eligible region; and
- Enhanced relationships amongst the four academic institutions, which may facilitate further cross-border projects.

The principal aim of the NWCAM project is to manage a programme of commercially driven Advanced Manufacturing research within the Health and Life Sciences Sector within the Eligible Region. The Partners wish to ensure that the benefits of the Project are felt across the North West part of the Region and therefore identified industrial partners from this part of Northern Ireland and the Border Region of Ireland to co-develop the research programme accordingly.

The NWCAM project partners also suggest that they are implementing a number of activities to enhance the effectiveness of cross-border collaboration in relation to the specific objectives and new ways of working that would otherwise not be possible in the absence of INTERREG VA. These include:

Joint Development	According to the project partners, the project concept and model was developed on an entirely cross border basis by the partners. Subsequent to the development of the Project Model, the Partners embarked on a series of meetings with representatives from eight industrial partners, which were conducted on a cross border basis.
Joint Financing	Although financially administered by the Lead Partner C-I, the Project is jointly financed by each of the Project Partners. This joint financing is in terms of in-kind contributions and the management of individual project budgets.
Joint Staffing	The Project is staffed on a cross border basis. A number of existing and new staff have been required to deliver the Project within each of the Partner organisations.
Joint Implementation	The Project partners indicate that the project model has been designed to ensure the effective collaboration between C-I, given its networks and knowledge of the regional economy, with a number of the best Advanced Manufacturing researchers from Northern Ireland; the Border Region of Ireland; and Western Scotland. In addition, to cross border collaboration within each individual Thematic Research Areas, the PI is leading the ongoing integration of all four thematic areas through the management of quarterly Project Team Meetings, facilitating the capture of spillovers. The manner in which this will be facilitated is outlined below in Table 3.16.

Table 3.16: Thematic Research Area Integration

	Additive Manufacturing	Nano-Manufacturing	Sustainable Manufacturing	Advanced Polymer Products
Additive Manufacturing		Surface texturing of AM materials - control of cell adhesion, incorporation of a plasmon in structures.	Development of new AM technology to reduce laser power, processing times, production of degraded material.	New engineering-grade materials to suit AM processes which will greatly extend the capability of AM.
Nano-Manufacturing	Prototyping of advanced packages for chip-level devices effect for diagnostics. Microfluidic substrates for chip-level devices.		Provision of exemplar processes and systems to illustrate sustainable approaches. Identification of new opportunities to sustainability of NM processes.	New materials, design techniques and process options for the production of nanostructures devices.
Sustainable Manufacturing	Near net shape manufacturing with the associated reduction in material and energy utilization.	Substitution of high cost/energy/waste processes and equipment with simple stamping and moulding processes for volume manufacture		Material and design developments to enable lightweight, recyclability and reduced energy to manufacture.
Advanced Polymer Products	Ability to manufacture complex shapes in a single operation.	Surface texturing of polymers for additional functionality.	Better process understanding and control will enable products with tighter tolerances and new application areas.	

The project partners have also provided (at July 2019) details of activity that they have been involved in that they suggest reflects the softer contribution of Catalyst team to the NWCAM project in terms of consortium building and developing new cross-border relationships. This activity is summarised in Appendix IV.

3.9 Impact on Business and Industry

This section considers the impact of the NWCAM project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research. Notwithstanding this, the Project Partners note the following positive activities and outputs, which offer the potential to support the longer-term growth and competitiveness of the project's industry members.

- **Development of industrial competencies** - For example, Nuprint's competencies have been developed as a result of undertaking a pilot project with Altnagelvin hospital-based around smart labelling for secure patient information transfer;
- **Development of IP** - As part of the 'Development of insulated medical tubing with controlled gas barrier properties' research project an assessment of the patent landscape has been conducted via Ulster's technology transfer office and an invention disclosure relating to this project is currently being assessed for patentability with an aim of filing a UK patent application. The project's industry partner (Armstrong Medical) will ultimately have the opportunity to be 'first-to-market' with the technology providing them with a potential competitive advantage;
- **Development of healthcare products** – It is noted that:
  - Causeway Sensors is creating a point of care diagnosis prototype machine for sepsis;
  - Leckey is in the process of creating new disability products with sensors specific to patients for comfort, heat control and pressure points;
  - Armstrong Medical is developing patient care products to reduce the nursing time for equipment changes; and
  - axial3D pioneering medical surgery technologies to speed up transplant surgery and improve success rates;
- **Development of new materials** in a new sectoral area (e.g. Denroy).

Furthermore, anecdotal feedback from the Project Partners suggests that the project has served to (at least in part):

- Increase businesses' knowledge and understanding of the benefits of working collaboratively with academic institutions which may result in the development of longer-term working relationships;
- Linked to the previous point, the Project Partners note that businesses have developed a greater understanding of the respective research strengths and capabilities that exists within the academic institutions; and
- Increase academia's understanding of the needs of industry.

3.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the NWCAM project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

3.10.1 EU2020 Objectives

The NWCAM project continues to offer the potential to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth. The project partners suggest that the project will contribute to the further development of the Regional Knowledge Economy through the development and implementation of 15 individual and bespoke R&I projects.

Furthermore, the NWCAM project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

3.10.2 The Atlantic Strategy

The NWCAM project does not offer the potential to directly contribute to the aims and objectives of the Atlantic Strategy.

3.10.3 The Horizontal Principals

The NWCAM project is anticipated to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

<table>
<tr>
<td>Sustainable Development</td>
<td>The Project Partners each agreed to align their activities with the Lead Academic Partner's (Ulster University) Environmental Sustainability Policy. This states that while the University appreciates that its activities (including R&I) have both direct and indirect environmental impacts, it views the protection of the environment as an integral part of good institutional practice. To support these aspirations, the University is and hence the Project Partnership is committed to:

Developing an environmental management system to effectively manage environmental impacts;
Continually improving environmental performance through the effective implementation of environmental improvement initiatives;
Reducing, and where possible preventing, pollution through the effective and efficient use of resources;
Complying with all relevant environmental legislation and other environmental requirements; and
Communicating this Policy effectively to all Project partners and stakeholders.

In the course of developing the Project, the Partners suggest that they adhered to and incorporated Sustainable Principles as follows:
<table>
<tr><td>Economic Benefits</td><td>C-I commissioned an economic impact assessment (undertaken by the NI Centre for Economic Policy) which they state indicated that the (proposed) investment could result in approximately £3m in additional GVA to the Regional economy.</td></tr>
<tr><td>Education and Skills</td><td>The Project involves four of the Region's largest third-level education institutions. The project will result in an additional 24 PhD and PDRA students expanding their skills and education base with direct relevance to high-value sectors across the Region. All the academic partners have a dual remit of Teaching and Research. The project partners consider it to be inevitable that the Project will result in elements of the proposed R&I being incorporated within future teaching provision.</td></tr>
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<tr><td>Job Creation</td><td>The Project will result in an additional 24 full-time PhD and PDRA positions within a five-year period.</td></tr>
<tr><td>Health and Wellbeing</td><td>The Project Partners anticipate that the project will result in a strengthened Regional Health and Life Sciences sector through the creation of a target number of new products and processes.</td></tr>
<tr><td>Equality and Poverty</td><td>Central to the Project design is the fact that it will facilitate R&I provision in a part of the Region considered to be more peripheral. The project partners consider that this will redress the fact that traditionally R&I investment is directed towards large, metropolitan areas.</td></tr>
<tr><td>Culture</td><td>The Project Partners anticipate that the project will result in an enhanced R&I culture across the Region.</td></tr>
</table>
In relation to Project delivery and implementation, Project Partners are undertaking the following sustainable actions:
i. <u>Travel, Communications and Project Delivery</u> – Whilst the Partners are encouraging and facilitating the maximum level of cross border interaction possible, and consider that face-to-face contact is important to assist with relationship development, the Partners are advocating the use of technology wherever appropriate to manage communications between the partners and stakeholders.;
ii. <u>Project Materials</u> - While some paper-based programme materials will be required, the Partners have adopted the use of electronic-based materials where possible.
iii. <u>R&I Activities</u> - All direct R&I activities associated with the Project are being conducted in line with Sustainable Development guidance and principles.
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<tr>
<td>Equal opportunities and non-discrimination</td>
<td>
The Project Partners state that they are committed to ensuring that equality runs central to all Project activities. They consider that this will ensure compliance with Regional equality legislation, including that pertaining to Northern Ireland; the Border Region of Ireland; and Western Scotland.
As a Designated Body, C-I (Lead Partner) is required under Section 75 of the Northern Ireland Act (1998), to conducts its operations (which will extend to the proposed Project) with due regard to the need to promote equality of opportunity:

Between persons of different religious belief, political opinion, racial group, age, marital status or sexual orientation;
Between men and women generally;
Between persons with a disability and persons without; and
Between persons with dependants and persons without.

The project partners suggest that equality considerations have run central to Project Design. The location of the NWCAM project within the North West is suggested to be a deliberate attempt to redress the lack of R&I investment in this more peripheral and rural area of the Region.
C-I has noted that in order to help ensure ongoing adherence to Regional equality legislation, as part of its monitoring and evaluation practices, it will systematically conduct an equality screening of the Project. In doing so, the following criteria will be considered:

The likely impact on equality of opportunity for those affected by the policy;
Opportunities to better promote equality of opportunity for people within Section 75 categories;
The extent to which the policy is likely to impact on good relations between people of different religious belief, political opinion or racial group;
Opportunities to promote good relations between people of a different religious belief, political opinion or racial group.

C-I will work with the Project Partners to ensure that any equality deficiencies identified in the course of Project delivery are redressed as quickly and as efficiently as possible.
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<tr>
<td>Equality between men and women</td>
<td>
C-I states that it is committed to the promotion of gender equality and subscribes to the view that diversity is a performance driver, and notes that the recruitment of all Project staff, including four Management and Administration; and 24 PhDs and PDRAs has been undertaken in line with the relevant legislation, with a number of females recruited for these positions.
The partners note that the project's original PI was a high-profile female Engineer from the Region. Albeit, this individual subsequently left the position.
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3.10.5 Contribution to Other Strategies

The NWCAM project aims to support the development of a more prosperous economy by increasing the commercialisation of new products and processes, resulting from innovation. As such, the Project Partners consider that the NWCAM project has the potential to contribute to a number of economic and innovation related strategies in each of the three jurisdictions, including:

Europe	• NWCAM also aligns with the **EU's SMART Specialisation Strategy** in that it will facilitate a concentration on two of Regions core sectors; Health and Life Sciences and Manufacturing.
Northern Ireland	• **NI Draft Programme for Government 2016 - 2025** - The Draft Programme for Government Framework for NI 2016-25 contains 14 priority areas including (i) Developing a competitive, Regionally balanced Economy. The primary purpose of Priority is to achieve long-term economic growth by actions including "stimulating innovation, R&D and creativity and supporting conditions, where a greater number of businesses are competing successfully overseas". It highlights the importance of North / South linkages to help deliver upon these priorities and a commitment to work closely with Ireland in ways that are both practical and mutually advantageous. • **NI Economic Strategy – Priorities for Sustainable Growth and Prosperity (2012)** - The key drivers of this Strategy are considered to be innovation, R&D and the skills of our workforce. • **Regional Innovation Strategy Action Plan 2014 - 2025 (DfE)** - The Strategy outlined the requirement to address the main barriers to innovation, which include factors such as skills, issues, knowledge and cost. It includes four key actions to maximise knowledge exploitation across Northern Ireland, one of which is to support the expansion of Catalyst Inc (C-I).
Ireland	• **Action Plan for Jobs 2016 (DJEI)** - The Action Plan highlights the importance of R&I to build competitive advantage and drive job creation. With regard to Manufacturing specifically, the Plan outlines the need for support in the area of Advanced Manufacturing R&I in addition to the provision of training and services for the benefit of both indigenous and multinational companies. • **Innovation Ireland (Report of the Innovation Taskforce 2010)** - As part of the Innovation Ireland Report, the Taskforce establishes a vision that by 2020 Ireland will be an Innovation Hub with a significant number of large world-leading, innovation-intensive companies with economic success dependent on increasing levels of innovation across all aspects of Irish enterprise including SMEs. • **Innovation 2020: Excellence Talent Impact (DJEI)** - A key ambition of the Strategy is to increase total investment in R&D in Ireland, led by the private sector, to 2.5% of GNP. On current official projections, this would mean that over €5billion will be invested per year in R&D by the private and public sectors by 2020. This will represent almost doubling current levels of investment (€2.9billion in 2014). • **Sharing our Future: Ireland 2025 (Forfas)** - As part of the sharing our Future report, Forfás confirms that R&I is crucial for economic and social progress and emphasised the importance of developing products and services in areas such as healthcare and environmental technologies.
Scotland	• **Renewing Scotland: The Government's Programme for Scotland 2015-16** - In its 2011-12 Programme for Government (PfG), the Scottish Government states the importance of "bringing creativity and innovation back to the heart of the Scottish way of life" and Government "works to create the best possible environment for entrepreneurship, innovation to flourish". • **Scottish Economic Strategy 2015** - Scottish Enterprise has established the ambition to help to make Scotland more globally competitive. Of particular relevance to the proposed project, a key priority is Innovation – Within its Business Plan, Scottish Enterprise suggests that innovation "is the lifeblood of long-term economic success". The Plan suggests that the Scottish Government will simplify its approach to supporting innovation and commercialisation, working in conjunction with partners to foster innovation and turn great business ideas into commercial success in the shortest possible timescales

In summary, the Evaluation Team is of the view that the NWCAM project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

3.11 Barriers to Cross-Border Cooperation

The NWCAM project partners indicate that they have encountered a number of barriers to cross-border cooperation that the priority axis is not addressing. These include:

- Visa restrictions relating to some (prospective) researchers – dependant of their country of origin and type of visa;
- The future implications of Brexit for freedom of travel; and
- Limitation of the eligible region to the border regions of Ireland (as opposed to the whole Island of Ireland) inadvertently narrows the mind-set of partners wider opportunities.

3.12 Exit Strategy

According to C-I, the NWCAM project is fundamental to its strategic aim to build upon the impact of the INTERREG IVA funded North West Region Science Park, and as such anticipate that they will lead the other project partners to identify and pursue other national and EU funding opportunities (including Horizon 2020) for cross border research to sustain and further develop the Project.

The NWCAM project partners anticipate that the project will result in the creation of 15 new products and or processes and the commercially focused development of 24 new researchers; which they envisage will have a considerable medium to long-term impact on the regional economy.

In addition, they suggest that the enhanced relationship that has been engendered amongst the project partners will leverage ongoing benefits to the Region.

The project partners further note that Derry City and Strabane District Council views the Project as a key part of its wider investment and growth ambitions, and has included it within the DCSDC Community Plan. According to the NWCAM partners, this provides the Council with a mandate to work with Project Partners, other local authority partners, stakeholders and beneficiaries to ensure the ongoing sustainability of the Project and, ultimately, the creation of physical infrastructure to anchor and enhance the work of the Centre as a net contributor to the North West Eligible Region.

4. RENEWABLE ENGINE

4.1 Introduction

This section of the report considers the Renewable Engine project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry relevant research and innovation capacity across the region.

4.2 Project Overview

4.2.1 Background

The Renewable Engine project partners suggest that the need for the project can be distilled into two key statements:

1. The renewable energy (RE) industry is expanding rapidly. New wind, solar and hydropower sources were added at the fastest rate the world has yet seen in 2015[40];
2. The stock and quality of R&D&I in an economy is vital for economic growth. Companies that undertake R&D&I are leaders in their field, competing on uniqueness and value rather than cost. These companies employ highly skilled individuals, pay high wages and generate income to NI from export sales[41].

The project partners consider that the rapid growth of the renewable energy industry presents opportunities both locally and internationally, with there suggested to be over 500 companies in the eligible region involved in renewable energy generation, storage and connection. However, the project partners note that despite a strong policy focus on innovation, expenditure on R&I remains low with Northern Ireland and Scotland having the lowest number of innovation active firms (55%) and patent applications of the 12 UK regions[42][43]. R&D expenditure in business and government institutes is well below the UK and international levels. They note that whilst the Republic of Ireland fares better in the innovation league tables and expenditure is growing, it also remains below EU and OECD average levels.

The project partners' own research with businesses in the eligible region indicates that many lack the awareness, resources and infrastructure to capitalise on the new innovation opportunities in the renewable energy (RE) sector. In addition, they note that PhD level research has been shown to be lacking industrial relevance on many occasions[44]. The Renewable Engine project is seeking to address this by combining the project partners' industrial linkages, knowledge of the renewable energy sector and academic capabilities.

The project partners have developed the following 'problem tree' which they suggest the Renewable Engine project will serve to address.

[40] http://www.ren21.net/status-of-renewables/global-status-report/
[41] EAG Competitiveness Report, July 2016
[42] UK Innovation Survey, Department for Business, Innovation and Skills, 2008.
[43] UK intellectual property office, 2010
[44] EAG Competitiveness Summary, July 2016

Figure 4.1: The 'Problem Tree' which the Renewable Engine project seeks to address

Cause

- Weak open innovation practices by companies hampering the development of cross-border partnerships;
- The gap between academic research outputs and commercialisation activity;
- Lack of technology sophistication and advanced manufacturing capacity and capability in engineering and manufacturing businesses in the region;
- Lack of sustained pipeline of high calibre staff with specialist knowledge of commercial technologies in the RE sector;
- Underrepresentation of higher value sector with strong export potential;
- Lack of innovation as a result of current the partnership approach between the academic, private and public sectors;
- University vision of research of global impact limits the drive to pursue regional innovation capabilities;
- PhD research lacking industrial relevance

Problem

Regional enterprises not engaging in research and innovation activity in the renewable energy sector in a strategic and collaborative manner

Effects

- Lower levels of economic growth and productivity;
- A deficit of locally owned intellectual property, spin-out and licensing activity in the RE sector;
- The region cannot fully contribute to the European renewable energy targets;
- Low levels of R&D&I expenditure and a small number of 'innovation active' businesses in higher-value sectors;
- Disconnect in the industrially strong border region from the most dynamic, knowledge-centric, parts of the island of Ireland and Scotland;
- Insufficient applied research capacity and commercialisation activity;
- Climate change impacts not mitigated through a lack of development in the RE sector;
- Economies of scale in R&D not exploited.

4.2.2 The Renewable Engine project

There is a strong advanced manufacturing and engineering industrial base in the region. However, there is limited activity and innovation in the production of products for the renewable energy sector. The project partners consider that engineering companies based in the eligible region have the potential to design and manufacture RE products with global significance for a growing market.

The Renewable Engine project intends to provide innovation support to businesses that typically lack physical facilities and equipment to carry out R&I activities to enable them to exploit new technology and sectors. Through this support, the project is seeking to position the region as a centre for the development of smart and innovative technologies through the development of a cross-border 'super-cluster' model, involving high calibre research and industry partners. Importantly, it is anticipated that this new collaboration will, for the first time, bring cross-border research centres together across the disciplines of advanced manufacturing **and** renewable energy and this will catalyse the change needed.

Figure 4.2: The Renewable Engine Research Supercluster

The project builds on existing infrastructure in the region with two of research partners, South West College and IT Sligo, who share a strong track record of applied R&I in renewable energy through the cross-border CREST infrastructure.

The 'Renewable Engine' partnership will also bring international research advanced manufacturing excellence through Queen's University and the UK Advanced Manufacturing Catapult centre based at the University of Strathclyde. Both these universities have research profiles within the top 15 in the UK. Private sector input will drive the supercluster through the inclusion of Manufacturing NI and Action Renewables as associate partners. It is anticipated that their input, as associate partners, will bring impartial representation from the private sector.

Mid Ulster District Council has also been included in the Project Partnership as an associate partner providing an advisory role (on the basis that the Council contributes the largest level of GVA from manufacturing in NI and has the highest number of citizens engaged in advanced manufacturing employment).

The Renewable Engine project partnership, which is led by South West College (SWC), is summarised below:

Table 4.1: The Renewable Engine project partnership			
No.	**Partner name**	**Abbreviation**	**Country**
1.	South West College	SWC	Northern Ireland
2.	Queens University	QUB	Northern Ireland
3.	Institute of Technology Sligo	ITS	Ireland
4.	Advanced Forming Research Centre (University of Strathclyde)[45]	US	Scotland
5.	Manufacturing NI	MNI	Northern Ireland
6.	Action Renewables	AR	Northern Ireland
7.	Mid Ulster District Council	MUDC	Northern Ireland

It is anticipated that the R&I supercluster will include 3 Principal Investigators (10% time), 4 full-time post-doctoral researchers, 12 PhD students and 3 R&I co-ordinators working with a minimum of 8 industry partners.

R&D activity within RE is being delivered through three cross border research programmes focussed on three thematic areas:

1. Additive Manufacturing;
2. Renewable Energy Technologies; and
3. Intelligent Manufacturing Systems.

Figure 4.3: Summary of Thematic Areas

Project Partners state that the research programme will focus on 3 key research areas:

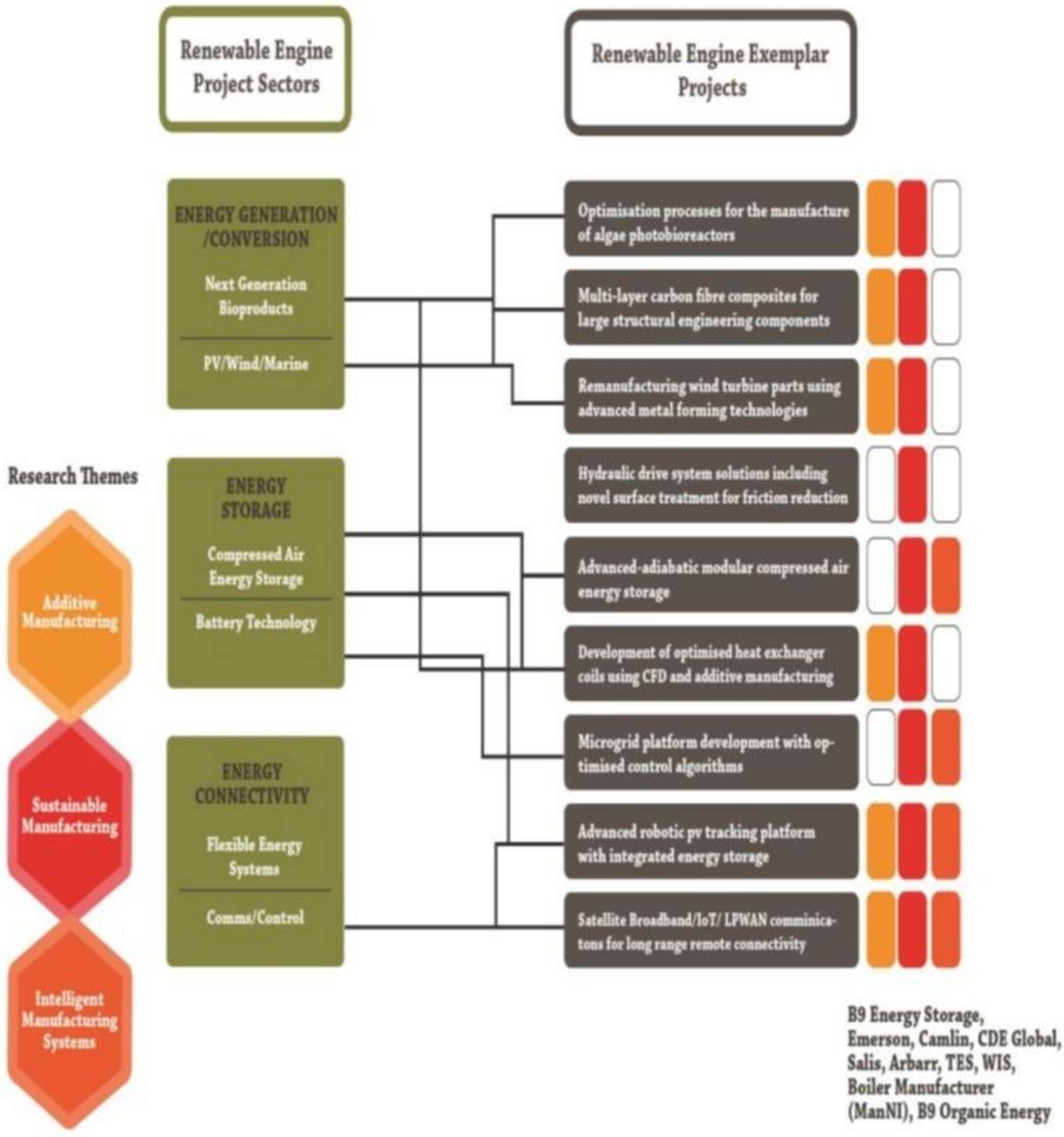
1. Energy generation;
2. Energy storage; and
3. Energy connectivity.

Specific technology categories are anticipated to include energy storage, anaerobic digestion, flexible networks, marine, additive manufacturing; design optimisation and modelling; vision and tactile sensing; flexible manufacturing systems; computer integrated manufacturing; modelling methods for rigid-body mechanics (e.g. dynamics, vibration, stability); metal forming, remanufacturing and

[45] The Advanced Forming Research Centre (AFRC) is a globally-recognised centre of excellence in innovative manufacturing technologies, R&D, and metal forming and forging research. This High-Value Manufacturing Catapult is a collaborative venture between the University of Strathclyde, Scottish Enterprise, UK Government and leading multinational engineering firms. The £80m facility has a world-leading reputation for research and focuses on using its production-scale facilities to take new R&D up the TRL scale and accelerate its industrial exploitation. The AFRC is one of only seven High-Value Manufacturing Catapult centres in the UK.

recycling, smart, multifunctional and self-healing materials, polymer nanocomposites, sustainable manufacturing (light-weighting, cycle time reduction, reduced energy processes), sustainable materials (biopolymers, bio-waste and natural filler/fibre reinforced composites, polymers/composites from waste streams, recycled carbon/glass fibre composites).

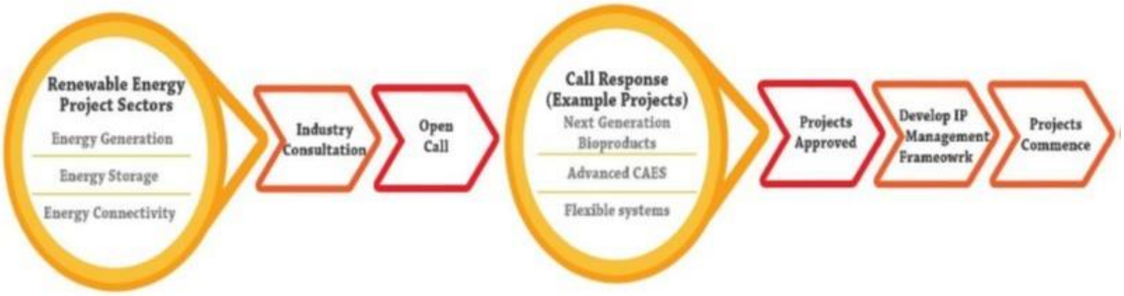
Figure 4.4: Summary of Research Sectors



It is noted that in advance of the submission of their funding submission, the Project Partners' engagement with the private sector resulted in the development of a series of exemplary research project briefs, as illustrated above.

A series of workshops have been delivered by the project partnership to educate manufacturing businesses of the opportunities that exist within the renewable energy sector and to raise awareness of the programme amongst industry. These workshops were also used to reach a consensus of the types of projects that were targeted by the 'Open Call' process.

Figure 4.5: Summary of Project Section Process



Subsequently, all interested parties and potential applicants were invited to participate in the 'Open Innovation Call' process through a series of Project Development Workshops, with xx businesses selected to participate in the research projects. This process was open to businesses of any size, working individually or collaboratively with other industry partners. To be in scope, each project proposal had to:

- Demonstrate transformational or disruptive, market-led innovation leading to novel, new products, processes or services or bring about a significant improvement in existing products, processes or services;
- Articulate a clear, anticipated growth and commercialisation impact for the business(es) with considerable, demonstrable potential to lead to a significant return on investment (ROI); with
- Priority is given to proposals that were considered likely to lead to sustainable gains in productivity and/or access to new overseas markets through export-led business growth.

Each project has been assigned at least 1 PhD student who is working on the project on a full-time basis with full academic support from the project partners. A minimum of 8 of the PhD researches will be aligned directly to the industry projects plus 50% of each of the Post Doc researchers. The remainder (4 PhD researchers plus 50% Post Doc plus Principal Investigators) will be on research projects within the partner institutions.

The Project Partners have also allocated up to €350,000 to directly support innovation projects in the open call[46]. Successful applicants to the Open Innovation Call are able to attract funding towards their eligible project costs via an additional application round. The percentage of costs that the project partners will pay varies depending on the type of research being carried out and the size and type of organisation involved.

The purpose of the grant funding is to assist the industry partner in developing their project proposal in a manner that supports the objectives of the Renewable Engine project. For example, this may include providing support to the associated PhD research project through the provision of technical assistance, demonstration equipment etc. To be in scope, a proposal must:

[46] A first round opened during 2018. Close to €200,000 was allocated within the first round of funding. In this first funding round, three businesses were successful in their applications to receive funding to support their research project proposals: Organic Power Ireland Ltd, Soltropy Ltd and Platinum Tanks. A second round opened on 1st July 2019.

- Demonstrate transformational or disruptive, market-led innovation leading to novel, new products, processes or services or bring about a significant improvement in existing products, processes or services;
- Articulate a clear, anticipated growth and commercialisation impact for the business(es) with considerable, demonstrable potential to lead to a significant return on investment (ROI);
- Demonstrate how the grant funding will be used to support the company's submission under the Renewable Engine Open Call for projects;
- Demonstrate how the grant funding will be used to support or complement the work of the PhD research being undertaken as part of the Renewable Engine Open Call for projects.
- Priority will be given to proposals that are likely to lead to sustainable gains in productivity and/or access to new overseas markets through export-led business growth.

Each project is anticipated to last between 36 and 48 months.

4.2.3 Management Arrangements and Governance

As lead partner, SWC is responsible for the overall project management of Renewable Engine. Financial management will be undertaken by the Project Manager with support from a dedicated project finance manager and team. A Project Board has been established, which will be responsible for monitoring the implementation of the project and for providing oversight and strategic direction. Each project partner will have one representative (minimum) and the group will meet quarterly for the duration of the project. In addition, an International Stakeholder Group will be established which will ensure that the R&I supercluster can draw on a range of disciplinary perspectives and public and private sector expertise.

As lead partner, SWC is responsible for the overall project management of Renewable Engine.

A Project Board has been established, which is responsible for monitoring the implementation of the project and for providing oversight and strategic direction. Each project partner has one representative (minimum) and the group will meet quarterly for the duration of the project. The Project Board includes representatives from an International Stakeholder Group. Key responsibilities of the Project Board include:

- Setting direction and management of the programme with approval for all major plans and deviations;
- Taking ownership of, reviewing, monitoring and seeking to ameliorate programme risks;
- Ensuring programme quality and valorisation of the project results;
- Developing a broad overarching framework for intellectual property including IP identification, protection and management;
- Ensuring visibility of state aid requirements and processes; and
- Development of a strategy to disseminate and promote the business take-up of research outcomes.

The Project Board is playing an important role in overseeing the development and implementation of the quality management system which the project partners suggest is critical to the successful delivery of the required outputs of the programme to the requisite standards.

In addition to the Project Board, an International Stakeholder Group has been established, which is chaired by the Catapult Centre. This group is helping to ensure that the R&I supercluster can draw on a range of disciplinary perspectives and public and private sector expertise. Its members include leading international and regional academics and industrialists in renewable energy and advanced manufacturing to help facilitate the project partners' understanding of the needs of and opportunities within the renewable energy sector. The International Stakeholder Group also consists of representatives from other stakeholder organisations with an interest in the project including (but not limited to) SEUPB, state agencies with responsibility for innovation (e.g. Invest NI, Enterprise Ireland, Scottish Enterprise, interest groups (UK Advanced Manufacturing Catapult, NI Matrix Panel, CASE, Action Renewables). To ensure a strategic conduit to the 'Renewable Engine' project, the International Stakeholder Group includes senior leaders from each of the project partners.

Six work packages have been established, with each of the partners responsible for the management of the delivery of a distinct work package.

Table 4.2: Overview of Renewable Engine Work Plans		
Work Plan	**WP Lead**	**Overview of key activities to be undertaken**
WP 1: Project Management	SWC	This work package will serve to ensure that all project objectives will be delivered on schedule according to the project work plan, and within approved budgets. Particular attention will be paid to financial co-ordination and the awarding and monitoring of grants and non-financial support to companies. This is likely to have significant state-aid implications. Accordingly, robust project and financial management arrangements will be put in place to ensure full EU legislatory compliance.
WP 2: Stakeholder Engagement	US	The Project Partners state that their engagement with stakeholders will ensure that the needs of industry are correctly addressed and integrated into the programme delivery. They note that their stakeholder engagement activity will include the implementation of the following key activities: • Establishment of an International Stakeholder Group; • The organisation of a schedule of activities including events, workshops, site tours and seminars built around sites of engineering and energy excellence; • Development of international linkages and utilisation of international expertise for the benefit of local industry and research partners; and • Support and advice to the Research Supercluster on the commercialisation of research and further signposting.
WP 3: Business and Industry Engagement	SWC	The project partners intend to implement a programme of engagement between the manufacturing industry and academic institutions for the delivery of R&I to stimulate the innovations required to develop the manufacture of renewable energy equipment within the region. It is suggested that a key value-added concept underpinning 'Renewable Engine' will be 'Open Innovation'. Thus, all 'Renewable Engine' R&I projects will be carefully selected through an open and transparent public application process, which will only develop projects that can demonstrate the potential for very significant strategic impact, meet defined commercial return on investment targets, and deliver key innovation in the renewable energy sector for local industry partners. The project builds on IT Sligo's successful model of engagement with industry, through a targeted outreach programme across the region and the provision of services, including intellectual property matters, technology transfer and commercialisation. It is anticipated that this will be achieved through the delivery of the following key activities: • Development of an Open Innovation Call for industry research projects in key potential growth areas; • Development of project briefs, establish multi-disciplinary, cross-border project delivery teams to include industry, academia, research and co-ordination partners; • Establishment of a robust partnership agreement with each of the companies that receive support, which will include the requirements that are necessary to be met in relation to State Aid and the financial amount agreed to be contributed by the participating company.
WP 4: Academic Research	QUB	The Project Partners anticipate that 'Renewable Engine' will deliver international excellence in the field of research for advanced manufacturing within the renewable energy sector. The project will implement European best practice on developing effective university-industry partnerships. The principle approach will be to provide an

Table 4.2: Overview of Renewable Engine Work Plans		
Work Plan	**WP Lead**	**Overview of key activities to be undertaken**
		accessible R&I infrastructure which targets collaborative industrial applied research which ascends the TRL ladder and bridges the gap between public and private R&I activity (TRL 2 to 6). It is anticipated that the majority of projects will be classified as industrial research, building on previous investigations and targeting experimental proof of concept and technology validated in research partner laboratory facilities for the development of new products, processes or services (TRL3-4). Prototyping and incubation (TRL5) activities, where the industry partner wishes to validate the technology in a relevant environment, will also be seen as an integral step towards industrial research. In such cases, it is expected that this will take place at the CREST Centre, Enniskillen where suitable test sites with pre-existing electricity grid capacity are available. State Aid funding rules will be applied depending on the category of research being undertaken, the size of the enterprise and level of collaboration involved. Delivery of the outputs for this work package will be achieved by focusing on the following key activities: • Provision of, and access to, state of the art Advanced Manufacturing Equipment to ensure that research teams can deliver research of world-class standard and in accordance with the requirements of the industry participants; • Applied Industrial Research Programme delivering to the needs of industry, collaborative in nature and fully integrated into the business plans of local businesses; • Participation by the Research Supercluster in 3 annual Research Colloquia to exchange and disseminate knowledge and progress from the research activity; • Publication of a minimum of 10 journal/conference publications.
WP 5: Quality of research outputs and of the implementation of the renewable Engine R&I supercluster	ITS	Progress and research impact will be measured through commercial return on investment targets and research target outputs (STs) which will include the publication of a minimum of 10 research papers in journals and at conferences recognised within the UK Research Excellence Framework (REF). The focus will be on international journals which concentrate on applied industrial research at a high standard of excellence. It is planned that all peer-reviewed journal articles and conference papers will be green open access, allowing free public access on the web, in order to accelerate the pace of innovation and impact of Renewable Engine research. Researchers will upload the final accepted version (post-print) of the article in their institutional research repositories. An "innovation management exploitation plan" will be defined to clarify the strategy and actions necessary, and to harmonise the innovation and exploitation activities of the partners. This plan will include consideration of technology transfer of project results, IP management stakeholder communication (including policymakers, industry networks and advisors). Delivery of these targets is anticipated to be assured through the following activities: • Development of a Quality Assurance Plan; • Innovation Management and Exploitation Plan; • Evaluation and impact assessment of IRP; • Development of an R&I Supercluster Future Strategy.
WP 6: Communication Activities	SWC	The Project Partners suggest that an appropriate communication, dissemination and exploitation strategy will be implemented to ensure that the objectives, deliverables and academic outputs developed within the Renewable Engine project are widely promoted to local industry, local and regional government, the wider scientific community, and international stakeholders.

4.3 Project Budget

The Renewable Engine project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €5,802,426.20 (ERDF plus Government Match Funding) to be expended and claimed by 31st July 2021, towards total anticipated project costs of €6,104,994.82 (see Tables 4.3 and 4.4).

Table 4.3: Anticipated Project Costs

Summary Budget	Total Project Costs (€)
Staff Costs	1,859,028.50
Office and Administration Costs	1,067,603.14
External Expertise and Services	2,484,211.13
Travel and Accommodation Costs	135,571.46
Equipment Costs	558,580.59
Total	**6,104,994.82**

Table 4.4: Anticipated Project Funding

Funding Sources	Total Value (€) (Public)
Cash Contribution (Partner Supplied/other grant)	302,568.62
Government Match Funding	734,608.84
ERDF	5,067,817.36
Total Grant Funding	**5,802,426.20**
Total Project Costs	**6,104,994.82**
Intervention rate (% ERDF)	83%

4.4 Anticipated Project Objectives, Outputs and Results

4.4.1 Objectives

The Project Partnership has developed 5 Strategic Objectives and 15 SMART objectives that it is seeking to deliver by the end of the project period. A summary of these is provided in Table 4.5.

Table 4.5: Renewable Engine Objectives and SMART Targets

Objective	SMART Target
1. Develop an internationally recognised cross-border research super-cluster in Renewable Energy and Advanced Manufacturing Technologies involving 4 research institutes to bridge the gap between public and private R&I	ST1. Recruitment of 1 Renewable Engine Project Manager, 3 R&I Co-ordinators, 3 Principle Investigators, 4 Post- Doctoral Researchers, 12 PhD students by (August 2017, M8).
	ST2. Recruitment of 8 industry partners by the end of Month 5 (June 2017). This will be achieved through an open innovation call for project proposals during Month 4 (April 2017) and Project Selection during Month 5 (May 2017)
	ST3. Cross-border Research collaboration between 4 research partners and 8 industry partners. As part of the Open Innovation call (M4), priority will be given for collaborative projects which are of a cross-border, transnational or interregional nature i.e. one or more companies collaborating with more or more research partner. All research projects will commence by August 2017 (M8) and be completed by end of July 2020 (M43)
	ST4. Cross-border knowledge exchange through 3 annual R&I Supercluster Research Colloquia as a method of exchanging and disseminating the progress and outcomes of the industrial research projects. The Research Colloquia will coincide with the duration of industrial research (M8-M43).
2. Facilitate direct knowledge transfer, technology development and innovation in 8 companies in the Renewable Energy Sector through the provision of R&I support and technology development grants to industry partners	ST5. Provision of non-financial support (expert advice, research support, use of equipment) to 8 industry partners. At least 8 enterprises will receive support as part of this project commencing by M8 and completed by M43. Each business will get a fully supported researcher to work on an industrial project that they have proposed and that has been agreed by the research partner no later than M9. Unsuccessful applicants for the call will be signposted (M10-M12) towards other suitable Innovation Programmes and Funding.
	ST6. Provision of technology and development grants to at least 4 of the 8 industry partners, collectively worth €350,000. The funding will be allocated according to the Open Innovation call guidelines which will be developed as part of the Programme Development task (M1–M3) as part of WP4. Funding will be issued to enterprises at the commencement of the research phase (M8) and no later than M32. This task will be led by the WP lead (SWC) and assisted by the research partners (QUB, US, ITS)

Table 4.5: Renewable Engine Objectives and SMART Targets	
Objective	**SMART Target**
3. Develop a novel programme of applied industrial research based on identified need leading to 57 years of research activity at PhD level or above	ST7. Produce a minimum of 10 peer-reviewed journal and conference publications in the Renewable Energy sector with cross border authorship and with the potential to create economic impact. The first peer-reviewed journal and conference publication will have been submitted by August 2018 (M20). All publications will have been submitted and published by M48.
	ST8. Recruitment and implementation of Renewable Engine Research Supercluster to deliver 57.05 full-time equivalent person-years of research activity at PhD level or above. The staff complement and associated number of FTE years contributed to the project are anticipated to be: – 3 Principal Investigators (x 10%) for 3.5 years each (1.05 years in total) – 4 Post-doctoral researchers for 3.5 years each (14 years in total) – 12 PhD Students for 3.5 years each (42 years in total)
4. Co-ordinate an international board of renewable energy stakeholders to drive innovative forward-looking applied industrial research and initiate policy dialogue	ST9. Recruitment of International Stakeholder Group involving a minimum of 12 organisations involved in the Renewable Energy and Advanced Manufacturing sector by the end of (M9). The I.S.G may include representatives from UK Catapult Network, KIT Germany, International Biogas Centre of Competence IBBK, Smart Grid Ireland, Scottish Renewables, University of Las Palmas, UK Energy Research Centre, Robert Morris University Pittsburgh, CENER National Renewable Energy Centre Spain, Luleå University of Technology, Sweden. This will be led by US with input from all partners and delivered under WP3.
	ST10. 2 biannual International Stakeholder Group meetings for the duration of the project from M10-M48 involving the 12 organisations recruited into the I.S.G and representatives from the Project Board. This will lead by US as part of WP3 which aims to incorporate the best and most suitable international industrial expertise in order to develop the project and take it forward and achieve the maximum benefit for businesses in the programme region.
5. Increase the knowledge and awareness within the industry in the cross-border region of R&I infrastructure in the Renewable Energy sector	ST11. 4 annual Renewable Engine events (M2-48) including Renewable Engine launch, technical workshops/seminars and final conference.
	ST12. Quarterly Renewable Engine Newsletter (M2-48) to include; background to the project, case studies from research activity, information on project events and articles from the International Stakeholder Group.
	ST13. A minimum of 5 press releases between (M2-48) at key milestones including; Award of funding, Renewable Engine Launch Event, case studies from cross-border research activity, grants awarded to Industry partners, Renewable Engine Final Conference.
	ST14. Weekly social media/website updates to occur for the duration of WP2 (M1-48), at both project and individual partner level.
	ST15. Attendance at a minimum of 5 cross-border seminars/workshops annually to disseminate Renewable Engine outputs.

4.4.2 Outputs

Per the Letter of Offer (dated 24th January 2017), the anticipated (approved) Renewable Engine Project Outputs are as follows:

Table 4.6: Anticipated Project Outputs

Programme Output	Name of Output	Programme Output Indicator Target[47]	Renewable Engine Project Target	Notes
CO01	No. of enterprises receiving support	20	8	It is anticipated that 8 Industry Partners will be recruited onto the project. An Open Innovation Tender process will be employed using Invitations to Tender (ITTs) to which industry will respond to become involved with the project. The Open Innovation Tender process will be advertised across the region to attract the companies most capable of delivering the innovations required under the programme.
CO02	No. of enterprises receiving grants	20	4	4 of the 8 enterprises will receive financial support to develop advanced projects which take new R&D up the TRL scale and accelerate its industrial exploitation. A total value of €350,000 has been allocated for the project's technology and development grants budget. The 8 industry partners who have been involved in a collaborative partnership with the research institutions will be informed of the grants available as their research project progresses and will participate in an open call to be awarded funding if they wish to further embed R&I activity. The industry partners receiving the financial support will contribute match funding through in-kind contributions, the level of which will be dependent on the aid intensity in line with Article 20 of Regulation (EU) 651/2014 and Article 25 of Regulation (EU) 651/2014.
CO04	No. of enterprises receiving non-financial support	20	8	The 8 industry partners will receive non-financial support in terms of guidance/expert advice, research support, use of equipment etc. from the four research institutions involved in the project (SWC, QUB, ITS, US). It is envisaged that this support will encourage the enterprises to become more involved in collaborative R&I.
CO24	Years of PhD (or above) level research	514	57.05	It is anticipated that Renewable Engine will recruit a total of 19 researchers to support the industrial research projects. This will include: • 3 x Principal Investigators (10%) for 3.5 years = 1.05 (allocated to QUB, ITS, US); • 4 x Post-doctoral researchers for 3.5 years = 14 (allocated to SWC, QUB, ITS, US); • 12 x PhD Students for 3.5 years = 42 (allocated to, 4 SWC, 3 QUB, 3 US, 2ITS). A total of 57.05 years of research activity will be delivered.
CO26	No. of enterprises cooperating with research institutions	10	8	Through both the non-financial and financial support provided, the 8 industry partners will cooperate with the 4 research institutions on their industrial research project specified in their individual collaborative research agreement.

[47] NB Appendix I provides an overview of the specific indicators relevant to Priority Axis 1, with associated targets, definitions and reporting details.

Table 4.6: Anticipated Project Outputs				
Programme Output	**Name of Output**	**Programme Output Indicator Target[47]**	**Renewable Engine Project Target**	**Notes**
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	8	The 8 industry partners will be active members of the Renewable Engine Research Supercluster and will participate in the 3 annual Research Colloquia to promote cross-border knowledge exchange on their individual R&I activity. As part of the Open Innovation call priority will be given to collaborative projects which are of a cross-border, transnational or interregional nature i.e. one or more companies collaborating with one or more research partner.
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	4	The Renewable Engine Partnership consists of four research institutions; South West College, Queens University Belfast, Institute of Technology Sligo and the UK Advanced Manufacturing Catapult.

4.4.3 *Results*

Per Table 4.7, it is anticipated by the Project Partnership that the Renewable Engine project will produce a minimum of 10 peer-reviewed journal and conference publications with cross-border authorship and with the potential to create economic impact.

Table 4.7: Anticipated Project Results

Programme Result Indicator	Target	Renewable Engine Project Target
The annual number of peer-reviewed journal and conference publications in the Health and Life Sciences and Renewable Energy sectors with cross-border authorship and with the potential to create economic impact	75	10

According to the project partnership, they will achieve the "peer-reviewed" aspect of the result indictor of through recognition of the publication within the UK Research Excellence Framework (REF)[48]. Prospective journals and conferences have been identified as follows:

International Journals	1. Composite Structures, Elsevier, ISSN: 0263-8223 2. Energy and Environmental Science, Royal Society of Chemistry, ISSN: 1754-5706 3. IEEE Industrial Electronics Magazine, Institute of Electrical and Electronics Engineers Inc., ISSN: 1932-4529 4. IEEE Transactions on Sustainable Energy. Institute of Electrical and Electronics Engineers Inc. ISSN: 1949-3029 5. IIE Transactions (Institute of Industrial Engineers), Taylor and Francis Ltd., ISSN: 0740-817X 6. Journal of Manufacturing Systems, Elsevier, ISSN: 0278-6125 7. Journal of Materials Processing Technology, Elsevier BV., ISSN: 0924-0136 8. Polymer Engineering and Science, Society of Plastics Engineers, Wiley ISSN: 0032-3888
International Conferences (All conferences run annually, and the project aims to target these and similar in the years 2018-2021 inclusive)	1. ICAMT International Conference on Advanced Manufacturing Technology (2016, 18th year) 2. American Society Mechanical Engineering ASME: Power and Energy Conference 3. ICME 2016 International Conference on Mechanical Engineering (2016, 18th Year). Schedules dates and venues up to ICME 2019 in Paris, France 4. ME's Additive Manufacturing + 3D Printing Conference and Expo (AM3D) 5. Affiliation of Rotational Moulding Organisations Conference (ARMO 2018, Hamburg Germany)

[48] REF is the system for assessing the quality of research in UK higher education institutions and is conducted jointly by the Higher Education Funding Council for England (HEFCE), the Scottish Funding Council (SFC), the Higher Education Funding Council for Wales (HEFCW) and the Department for Employment and Learning, Northern Ireland (DEL). The lead research partner in Renewable Engine, QUB was placed 8th in the UK for research intensity in the 2014 REF, with over 75% of research activity judged to be internationally excellent or world-leading. For the Unit of Assessment (UoA)/research area relevant to 'Renewable Engine', 'Aeronautical, Mechanical, Chemical and Manufacturing Engineering', QUB was rated as 6th in the UK for research intensity with 88% of research considered world-leading or internationally excellent. Over 90% of the research impact for this UoA was considered to be world-leading or internationally excellent demonstrating the track record of QUB researchers in this research area in delivering impactful research that can benefit the wider society and the economy. The expertise required to develop appropriate REF quality results will be shared with all project partners.

4.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the Renewable Engine project's key achievements and the extent to which the Renewable Engine project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

4.5.1 Key Achievements (to March 2018[49])

Consultation with the Project Partnership indicates that it has been successful in recruiting 10 businesses on to the Renewable Engine Project. These project beneficiaries include:

Table 4.8: Project business beneficiaries	
• Kingspan Water and Energy • Platinum Tanks • Rotosim Ltd. • Organic Power Ireland Ltd. • Kastus Technologies	• Caley Ocean Systems • B9 Energy Storage Ltd • Soltropy Ltd. • Doosan Babcock • Booth Welsh Automation

The Project Partnership had recruited a further 2 businesses (CDE Global and Warmflow Ltd.), however it is understood that these businesses decided not to progress with the project due to issues regarding the ownership of intellectual property (in the case of the former) and the inability to recruit a PhD student to undertake the work that was required given the specialised nature of the research project (in the case of the latter).

All project staff (including 12 PhD Students and 4 Post-Doctoral staff) have been recruited to support the delivery of the Renewable Engine Project.

To date, the project partners have commenced 12 research projects, as profiled overleaf:

[49] Please note that the key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing.

Table 4.8: Overview of RE research projects

Research Theme:	Project Title	Project Partners	Description	Project Team & Role Descriptions
Energy Generation	Development of Lightweight Rotomoulded Multi-Layer Structures for Off-Shore Energy Generation	Queen's University Belfast and Kingspan Water and Energy	The development of manufacturing processes for large, low cost and lightweight structural components is essential to the future success of the marine energy generation sector. Therefore, the development of multi-layer sandwich constructions for very large rotomoulded marine / off-shore / renewable energy sector components is very desirable. Foam is included to improve the stiffness per unit weight of the part, reduce costs and to act as a buoyancy aid. At present manufacturing of these structures is cost-prohibitive due to long cycle times and difficulties in controlling part cooling. New technologies such as Internal Mould Water Cooling have the potential to significantly advance the manufacturing processes and to provide a springboard for the development of new forms of structural components and new commercial opportunities. Working closely with Rotosim Ltd on the modelling of the multi-layer constructions will help to create a unique cross-border R&I 'supercluster' in the area of renewable energy and advanced manufacturing for rotational moulding. The aim of this project is to develop new rotational moulding technologies that are capable of producing large multi-layer polymer/foam sandwich structures that can cope with the challenges of the marine environment.	The Kingspan team will be led by Kingspan Technical Director Noel McQuaid aided by Kingspan Project Engineer Colin Finnegan and a dedicated team of research and development engineers at Kingspan sites based in Portadown and Castleblaney. The QUB research team will be led by Dr Peter Martin, who will act as Principal Investigator and overall manager of the project, assisted by Dr Eoin Cunningham. The work will be largely carried out by a PhD student (Alex Pritchard) closely supported by a small team of core staff from the PPRC consisting of Dr Mark McCourt and Mr Mark Kearns. Their role will be crucial to the success of the project as they will provide substantial practical and technical support to the PhD student during the experimental phases of the project. The PPRC has a well-established and extensive suite of rotational moulding equipment, test moulds and testing & analytical facilities that broadly encompass techniques for thermal, mechanical, rheological and surface characterization.
Energy Generation	Development of Hybrid Rotomoulded Composite Structures for Solar Panel Frames	Queen's University Belfast and Platinum Tanks	The aim of this project is to develop knowledge and understanding of how thermoplastic composite materials can be combined with the process of rotational moulding to manufacture structural parts such as solar panel frames. A range of test specimens combining rotational moulding and composites will be manufactured. Experimental data will be generated on the test pieces produced when their structural and thermal performance characteristics are measured. The learnings made will help to contribute to the design of a prototype tool which will be used to produce hybrid parts for solar panel frames.	The Platinum Tanks team will be led by Dr Oisin O'Conchubhair who is the Technical Operations Engineer. The QUB research team will be led by Dr Peter Martin, who will act as Principal Investigator and overall manager of the project, assisted by Dr Joe Butterfield. The work will be largely carried out by a PhD student (David Aleman) closely supported by a small team of core staff from the PPRC consisting of Dr Mark McCourt and Mr Mark Kearns. Their role will be crucial to the success of the project as they will provide substantial practical and technical support to the PhD student during the experimental phases of the project. The PPRC has a well-established and extensive suite of rotational moulding equipment, test moulds and testing & analytical facilities that broadly encompass techniques for thermal, mechanical, rheological and surface characterization.
Energy Generation	Simulation of the Advanced Manufacturing of Multi-layer Rotomoulded Structures for the Renewable Energy Sector	Queen's University Belfast and Rotosim Ltd	The aim of this project is the development of a multi-layer rotational moulding simulation and modelling programme specifically for the advanced manufacturing of renewable energy sector structures. Low cost, multilayer rotomoulded structures consisting of skin/foam/skin (for mechanical resistance) or 2 -3 different polymer layers (for chemical resistance) are increasingly suitable for the Renewable Energy sector. The low-cost tooling in the rotomoulding process makes multi-layer rotomoulded structures very attractive as a replacement for steel constructions particularly for large anaerobic reactor tanks, off-shore wave energy devices or solar panel array devices. Expected outcomes include new software/modelling package and enhanced process capabilities.	The RotoSim team will be led by RotoSim Ltd. Managing Director Dr Ed Wright. Ed Wright is also the developer and programmer of RotoSim software. The QUB research team will be led by Dr Peter Martin, who will act as Principal Investigator and overall manager of the project, assisted by Dr Joe Butterfield. The work will be largely carried out by a PhD student closely supported by a small team of core staff from the PPRC consisting of Dr Mark McCourt and Mr Mark Kearns. Their role will be crucial to the success of the project as they will provide substantial practical and technical support to the PhD student during the experimental phases of the project. The PPRC has a well-established and extensive suite of rotational moulding equipment, test moulds and testing & analytical facilities that broadly encompass techniques for thermal, mechanical, rheological and surface characterization.

Table 4.8: Overview of RE research projects

Research Theme:	Project Title	Project Partners	Description	Project Team & Role Descriptions
Energy Generation	Developing Small-Scale Off-Grid Renewable Power through Anaerobic Digestion	Institute of Technology Sligo and Organic Power Ireland Ltd	The benefits of anaerobic digestion (AD) are widely recognised but traditional systems have a relatively high fixed-cost precluding their wider use. This project aims to deliver a robust, modular, cost-effective small-scale system (circa 20kw/hour) including energy (battery) storage to match 24/7 power supply, with the normal peaks and troughs of demand. The system will be flat-packed, and operate inside two 40ft standard transport containers including all pumps, engines and the battery to give a plug-and-play system.	The Organic Power side will be led by Robert Brennan who will facilitate the industrial collaboration. Dr John Bartlett will act as lead academic at ITS with support from Prof Suresh Pillai. A Post-Doctoral Researcher will provide additional support to the PhD student (Sean O'Connor).
Energy Generation	Development of New Nanocatalysts for the Direct Conversion of Biogenic Carbon Dioxide to Sustainable Fuels	South West College	The aim of this project is the development of new nanocatalysts for the direct conversion of biogenic carbon dioxide (CO_2) to "drop-in" fuels in the gasoline range (C8-C12), resulting in a sustainable production route. Hydrogen will be utilised from renewable energies and CO_2 will be directly converted, which offers an attractive route for the efficient utilisation of CO_2 as a renewable feedstock.	NB This project is on the website, but not in materials sent.
Energy Generation	Physiochemical Characterisation and a Kinetic Investigation of Constituents Found in First-Generation (c-Si) Photovoltaic Modules	South West College	This project focuses on the development of a comprehensive characterisation study, kinetic and process model to further the understanding of the delamination and subsequent recovery of materials from an End-Of-Life (EoL) PV module using the thermochemical conversion method of pyrolysis. The aim of this project is to develop new recycling technologies that are capable of recovering constituents from a first-generation (c-Si) PV module whilst maximising yield and facilitating green manufacturing concepts like the circular economy.	NB This project is on the website, but not in materials sent.
Energy Generation	Developing Band-Gap Tunable Photocatalysts for the use of Energy Efficient LED Lamps	Institute of Technology Sligo and Kastus Technologies	The project will examine the use of energy-saving LED lights for the sustainable implementation of the green technology process, the photocatalysis. In conventional photocatalysis process, UV light is used for initiating the reaction due to the wider band-gap (3.2 eV for TiO2). However, UV light is not practical in all circumstances and is not energy efficient. Therefore, energy-efficient technology is required to implement photocatalysis for wider energy and environmental applications. This project aims to develop photocatalysts that can yield high efficiency under energy-efficient light sources (such as an LED) and extend their application to room interiors where there is relatively poor lighting/illumination.	John Brown founded Kastus in 2013 having worked closely with and funded the development team for over 10 years. He will be supported on the Kastus side by James Kennedy, Director of Innovation and Operations. ITS research team will involve Prof Suresh Pillai and Dr John Bartlett. A Post-Doctoral Researcher will provide additional support to the PhD researcher (Snehamol Mathew).
Energy Generation	Realising Heavy Lift Operations from Floating Vessels for Offshore Wind	University of Strathclyde and Caley Ocean Systems (Industrial Systems and Control Ltd)	As offshore wind farms become larger in magnitude and positioned further from the shore, there is a strong economic incentive to have the heavy lifts required for installation and Operations and Maintenance carried out by floating vessels rather than expensive and slow jack-up vessels. However, lifts from a floating vessel are heavily dependent on six-degree-of-freedom active control. High-performance control is essential for successful lifts in all but benign sea/wind conditions, especially as the payload becomes very large and critical. This project will study advanced control methods to widen the operating window and make heavy lifts from floating vessels viable.	NB This project is on the website, but not in materials sent.

Table 4.8: Overview of RE research projects				
Research Theme:	**Project Title**	**Project Partners**	**Description**	**Project Team & Role Descriptions**
Energy Storage	GENSSIS: Gravitational potential Energy Storage & Synchronous Inertial Stability, designed to provide, zero-emission, new system Ancillary Services	University of Strathclyde and Caley Ocean Systems (Industrial Systems and Control Ltd)	This early-stage project is examining the technical and commercial feasibility of a concept which could provide a range of zero-emission ancillary services relating to electrical power grid balancing infrastructure. Using existing technologies, a utility-scale, emission-free, gravitational potential energy storage system would deliver services such as Short-Term Operating Reserve, Fast Frequency Response, & Storage, to facilitate the increased grid integration of intermittent Renewable Energy.	NB This project is in materials sent, but not on the website. Caley's Technical Director will be supported on the industry side by Brendan McGrath. At UoS Dr Paul Blackwell will provide academic support with Simon Leslie (Knowledge Exchange Fellow). They will look to support the PhD student.
Energy Storage	Near Isothermal Liquid Piston Research and Innovation	South West College and B9 Energy Storage Ltd	B9 are currently developing Compressed Air Energy Storage (CAES) as part of the Horizon 2020 programme. Current studies show that liquid piston compression can offer an alternative to standard technologies with improved efficiency gains, reduced system complexity and cost. This technology is currently at a very low TRL level and so falls outside the scope of the H2020 project. The main objective of this research proposal is to develop a novel isothermal-CAES system using liquid piston technology.	B9 Energy has the role of determining the desired functional envelope of the reversible CAES machine, using the novel liquid piston design so that it will be compatible with the control strategy that has already been devised under the existing H2020 scope of work. The details around this include parameters such as starting, stopping, ramp rates, duration of operation, power quality and response times to dispatch signals. Technical Director of B9 Energy Storage Ltd, developed the CAES control strategy to maximise the revenue earning opportunity of the machine. QUB act as academic supervisor for this project. A Post-Doctoral Researcher at SWC provides additional support to the PhD student.
Energy Storage	Incorporating Heat Storage inside Twin-Walled Evacuated Tube Solar Collector	University of Strathclyde and Soltropy Ltd	The aim of this research project is to incorporate thermal storage inside twin-walled evacuated tube solar collectors. This increases the system efficiency, allows oversizing and so contributes to space heating without increasing the hot water cylinder size and can be used to preheat the water going to a combi-boiler, electric shower or electric boiler in properties without a hot water cylinder. This will be achieved using phase change materials or materials with high specific heat capacity. The challenge is to find a material that is affordable, safe and is compatible with all materials that it is in contact with.	At Soltropy, Stuart Speake (Solar Thermal Installer) and Martin Gilchrist (Senior Technical Design) will lead the industrial aspect of the project. At UoS Dr Paul Blackwell will provide academic support aided by Simon Leslie (Knowledge Exchange Fellow) to the PhD student (Fatin Abdalla).
Enabling Technologies	Techno-Economic Analysis of Decentralised Sustainable Energy Systems Installation and Market Potential at the Sector and System Level	South West College and Doosan Babcock	In the transition from current fossil-based energy systems to green-powered sustainable energy solutions, one of the many challenges facing both end-users and energy providers in the selection of the most optimal range of technologies that satisfies the trilemma of best economics, best environmental performance, and best social benefits. This is due to the fact that the optimal selection of renewable energy technologies is determined by a wide range of variables, parameters and constraints that make it difficult and time-consuming to make a decision based on simple human analysis. These factors include the technical potential of that technology within a particular locality e.g. solar, wind, prevailing economics in the area, available land area, value drivers of the customer, capital and operating cost of each technology type, end-user energy use volume and behaviour, etc. To enable ease of decision-making when installing green-powered energy solutions, this research will focus on developing methodologies, algorithms and optimisation metrics to enable easy visualisation of energy transition paths for various areas, sectors and customers. It is anticipated that this will lead to the development of an App for market use by both energy users, government policymakers and energy providers. This App will reduce the time wasted in carrying out green-power energy retrofits, as well as inherent human errors that have been identified in various designs. It would allow	Doosan Babcock Green Power Solutions in the UK is staffed with a knowledgeable team of techno-economic experts with three doctorate degree holders (in new energy systems) and a number of senior and well experienced new energy system experts. This support base is also backed-up by the wider group across the US and South Korea and the Middle East, from where relevant knowledge and expertise can also be drawn. Academic support will be provided by the University of Strathclyde by Dr Paul Blackwell. Rachel Coulter, Post-Doctoral Researcher at SWC will provide additional support to the PhD student (Maria Damaskou).

Table 4.8: Overview of RE research projects

Research Theme:	Project Title	Project Partners	Description	Project Team & Role Descriptions
			the selection of the global optima energy retrofit path, as compared to the present scenarios where green-powered energy retrofits have failed to deliver the anticipated energy savings at design due to the selection of a local optima point.	
Enabling Technologies	Industry 4.0 and Augmenting the Millennial Worker	University of Strathclyde and Booth Welsh Automation	Using Industry 4.0 technology, this project aims to develop a complete virtual/augmented model of a renewable power installation, ideally a wind turbine. The purpose is to create the Augmented Worker using existing and emerging technology. The information obtained from the research/survey phase would achieve a significant reduction in cost and risk on renewable projects. Having augmented information available virtually at the point of use is anticipated to improve right first time operation and maintenance and increase the availability of the asset	At Booth Welsh, the Senior Electrical Engineer, supported by the Lead Systems Engineer, and Commercial Director. UoS will provide academic support with help from Knowledge Exchange Fellow who will provide additional support to the PhD student.
	Industrial Scale PV Recycling Process	South West College and CDEnviro	This project aims to develop an industrial-scale pyrolysis system to bring about the rapid delamination of End-of-life (EOL) Photovoltaic (PV) modules. The pyrolysis system will thermally remove the individual, high value, constituent elements of the PV modules and simultaneously keep the whole module intact. This will result in direct re-use or the generation of multiple, concentrated, high-value recyclates, which can readily be processed and reinstated in the same or equivalent application. It is proposed that the by-product of the process, green syngas with high heating value, will be burnt to provide the energy source to run the system.	NB This project is in materials sent, but not on the website. The CDEnviro team will be led by Senior Product Development Engineer, Sean Dobbs, aided by Project Design Engineer, Peadar O'Hare, and Technical Engineer, Mark McFarland. The QUB research team will be led by Dr Xiaolei Zhang, assisted by Prof Adrian Murphy and Dr Rory Doherty. SWC Post-Doctoral Researcher, Rachel Coulter will provide additional support to the PhD student (Charlie Farrell). SWC will be the lead partner and will facilitate project review meetings, provide guidance to academic partners and oversee project-related expenses. Sean Dobbs will be the project lead within CDEnviro and will, therefore, manage the overall project whilst working alongside academic partners. Dr Xiaolei Zhang will be responsible for the communication/reporting of project milestones or any changes to the proposed milestones to CDEnviro which fall under the remit of QUB. Regular project review meetings will be held involving CDEnviro, SWC and QUB to ensure that the project schedule and listed work packages are being adhered to
	Development of Hybrid Renewable Heat Pump	South West College and Warmflow Engineering Co Ltd	To work alongside the Warmflow R&D team to assess and develop a hybrid heat pump for the UK market. This will take existing liquid fuel burner technology combine it with air source heat pump technology and PV power and encase it in a renewable polymer shell to make an extremely efficient renewable heating supply that will also be suitable for the retrofit market of existing housing stock.	NB This project is in materials sent, but not on the website. 3 Warmflow R&D Engineers will be actively applied to the project; Niall Dolan, Ian Henderson and Kenneth Heaslip. Academic Supervision will be provided by ITS (Dr Molua Donohoe & Dr Gerard McGranaghan). Rachel Coulter, Post-Doctoral Researcher at SWC will provide additional support to the PhD student.

As noted, it was anticipated that the Project Partners would allocate up to €350,000 to directly support innovation projects on the basis of competitive open calls. Successful applicants to the Open Innovation Call are able to attract funding towards their eligible project costs via an additional application round. The percentage of costs that the project partners will pay varies depending on the type of research being carried out and the size and type of organisation involved. A first-round opened during 2018 with circa €200k being allocated to three businesses to support their research project proposals:

- Organic Power – Development and testing of modular, small-scale Anaerobic Digestion system (approx. 20kw/hr) with incorporated battery energy storage. The aim is to overcome the high fixed cost involved with traditional AD systems.
- Platinum Tanks – Development and combination of thermoplastic composites with rotational moulding to develop structural frames for solar panels. This is an application where both mechanical and thermal performance is critical.
- Soltropy – Develop thermal storage within twin-walled evacuated solar tube collectors. The challenge is to find a suitable phase-change material that is affordable, safe and compatible with all other materials in the system.

A second-round opened during July 2019 (with a potential €150k available) but a decision has not (at the time of writing) been taken on the businesses anticipated to receive the financial support.

The Renewable Engine project partners also cite the project's key achievements (as of March 2018) as being:

Table 4.9: Examples of key achievements to date

Period	Dates	Key Achievements
1	1st January 2017 – 31st March 2017	• A programme was devised as to how best engage with businesses in the sector. Briefing events were delivered in order to raise awareness and foster interest and/or appropriate collaboration.
2	1st April 2017 – 30th June 2017	• Most activity related to industry engagement including information sessions, project development workshops and the call for applications. • Prospective projects were assessed, and feedback developed for industry applicants. • Knowledge of the specific areas of research allowed for other activities to progress, including the recruitment of post-doctoral and PhD researchers and the provisioning of equipment for research projects.
3	1st July 2017 – 30th September 2017	• Project Staff started - PDRAs at SWC and UoS and Programme Manager at SWC. • A second round of company applications (focused upon applications within the Scottish region) was requested. • An Approval Board meeting in September saw the final list of industrial partners and associated projects approved. • PhD recruitment continued with work liaising between applicants, potential academic partners and the approved industrial partners matching applicant skillsets with the project briefs and conducting screening and academic interview stages. • Initial work was carried out in setting up the International Stakeholder group. • Collaborative research agreements and the IP policy was developed/drafted. • A Renewable Engine Communications Plan was developed. • A Dissemination and Exploitation Strategy was developed.
4	1st October 2017 – 31st December 2017	• 7 PhD students had taken up position and all project staff were in place bar the ITS PDRA and R&I Coordinator positions, who were due to start in Period 5. • The Project Launch event was held during November with a wide range of stakeholders in attendance. A press release was disseminated alongside the launch event detailing the industry partners who had been approved to be a part of the project; helping define the industry-led research. • Plans for the first meeting of ISG commenced in order to frame the group activities. • A legally robust template for the collaboration agreements was completed, with SWC seeking professional advice to aid this development. Negotiation of IP arrangements was ongoing as a result. • All partners continued the drive for the recruitment of the final PhD positions. Partners also identified the equipment that they needed, as the research projects had been fully defined.
5	1st January 2018 – 31st March 2018	• The first International Stakeholder Group meeting was held at AFRC. • SWC co-ordinated the first Research Colloquium at Lusty Beg, NI (2-day event). • Project staff and students presented work at Environ conference in Cork. • QUB - All three members of the research team at this stage (2 PhD students + 1 PDR) produced technical papers, which were accepted for presentation at the ESAFORM 2018 Conference. • US - Attended networking events to promote the project including: UK/China supply chain workshop, Energy Technology Partnership, Energy, Society and People, Scottish Renewables Wind Conference, IET Event, Scottish Enterprise, Knowledge Transfer, Partnership event at University West of Scotland, IET event on Energy Storage, Materials Research Exchange, Scotland Innovates, Low Carbon Innovation funding workshop. Met with CeeD.

4.5.2 *Progress towards the Project's Output Indictors*

Table 4.10 provides a high-level summary of the progress that has been made by the Renewable Engine project towards its Output Indicators.

Table 4.10: Progress towards the RE Output Targets

Programme Output Code	Name of Output	Programme Output Indicator Target	Renewable Engine Project Target	Progress as of July 2019	Variance against project target	Comment
CO01	No. of enterprises receiving support	20	8	10	+25%	Proceeding according to the work plan. As noted, support continues to be provided to the following businesses: Kingspan Water and Energy, Platinum Tanks, Rotosim Ltd., Organic Power Ireland Ltd., Kastus Technologies, Caley Ocean Systems, B9 Energy Storage Ltd, Soltropy Ltd., Doosan Babcock, Booth Welsh Automation.
CO02	No. of enterprises receiving grants	20	4	3	-25%	Proceeding according to the work plan. Three businesses have been allocated a combined €200k in financial grants to date: Organic Power, Platinum Tanks and Soltropy. Further grant awards are anticipated to make following the second call for applications which was opened during July 2019.
CO04	No. of enterprises receiving non-financial support	20	8	10	+25%	Proceeding according to the work plan. As above
CO24	Years of PhD (or above) level research	514	57	24.42	43%	Proceeding according to the work plan. As above
CO26	No. of enterprises cooperating with research institutions	10	8	10	+25%	Proceeding according to the work plan. As above
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	8	10	+25%	Proceeding according to the work plan. As above.
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	4	4	-	Proceeding according to the work plan. Research Institutions engaged on the RE project include SWC, QUB, ITS and the University of Strathclyde.

In summary, the Renewable Engine project is progressing towards its project work plan and is on progress to achieve each of its respective output indictors.

4.5.3 Target Groups Reached

Table 4.11 provides an overview of the target groups reached as a result of the Project's activity to date.

Table 4.11: Target groups reached as a result of the RE project activity[50]

Target Groups	Target Value	Target Groups Reached (at June 2019)	Target Groups Reached June 2019 %	Description of Target Group inv.	Source of Verification
Higher education and research	15	31	207%	• 4 research organisations participating in cross-border R&I; • 3 Research Colloquium to promote knowledge transfer; • Dissemination of 10 peer-reviewed academic journals; • 4 RE flagship events.	Examples cited include: • Ulster University was in attendance at the launch event along with the Centre for Advanced Sustainable Energy. • The University of Liverpool was also involved in a strategy development workshop held at SWC CREST. • An Assistant Professor from Dublin City University has joined the ISG and took part in the first meeting. • The project was showcased to a number of Irish and Scottish academic representatives at the Environ conference in Cork, including; NUIG, DIT, TCD, UCC, CIT, DKIT, IT Carlow, UL, Glasgow Caledonian University and the University of Isles and Highlands. This was achieved through both oral and poster presentations by project staff and students.
SME	50	51	102%	• 8 enterprises participating in the R&I supercluster; • 4 enterprises receiving technology development grants • 4 RE flagship events to promote the dissemination of knowledge within the SME network; • Industry briefing events.	Examples cited include: • Platinum Tanks, B9 Energy, CD Enviro, Doosan Babcock, Booth Welsh, Kingspan, Bioil, Dimplex Renewables all attended the launch event. • Maus GmbH took part in the first ISG meeting. • SWC engaged with the Camlin Group at the Invest NI event in Glasgow. • SWC also engaged with DHD who are developing AR technology for wind turbine maintenance in collaboration with Digital Catapult NI.
Business support organisations	15	12	80%	Business Support Organisations will be targeted through: • Participation in the project board (Invest NI, Scottish Enterprise, Highlands and Islands Enterprise, Enterprise Ireland, Economic Development Directorate Scotland); • 4 RE flagship events.	Examples cited include: • Invest NI, IDA Ireland attended the launch event. • In addition to this, the European Institute for Innovation, Scottish Enterprise and the Ireland Institute of Pittsburgh were part of the ISG and took part in the first meeting. • SWC met and presented its research to Digital Catapult NI who are developing AR technology for wind turbine maintenance alongside DHD.
Regional public authority	8	8	100%	Regional public authority will be targeted through: • Direct involvement in the project as an associate partner (Mid-Ulster Council); • Participation in the Project Board (DfE, DJEI); • 4 RE flagship events	Examples cited include: • Mid Ulster Council attended the launch event along with DfE and the Executive Office. • Cork County Council were reached through the Environ event, at which they were involved and in attendance.
Sectoral agencies	5	10	200%	Sectoral agencies will be targeted through: • Direct involvement as associate partners (Manufacturing NI, Action Renewables); • Participation in the international stakeholder group	Examples cited include: • Manufacturing NI, Action Renewables, Meath Energy Agency attended the launch event; • The Environmental Protection Agency (Ireland) and the Environmental Science Association of Ireland were both engaged with Renewable Engine projects at the Environ conference held in Cork.

[50] Source: SWC individual Partner Reports (1st April 2019 – 30th June 2019)

4.5.4 Progress towards the Project's Result Indicator Targets

Per Table 4.12, it is anticipated that the Renewable Engine Project would contribute 10 peer-reviewed journal and conference publications with cross-border authorship.

Table 4.12: Progress towards the RE Results Indicator

Name of Output	Programme Target	Renewable Engine Project Target	At July 2019	Comment
No. of peer-reviewed journal and conference publications with cross-border authorship	75	Minimum of 10	0	Proceeding according to the work plan. 4 peer-reviewed journal and conference publications with cross-border authorship currently in progress

To date, the project has not finalised any peer-reviewed journal and conference publications with cross-border authorship, albeit the Project Partnership notes that, at the time of writing, 4 are currently being progressed/prepared.

4.5.5 Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives

The Project Partners advise that the project has only encountered minor issues in the delivery of the Renewable Engine project to date and does not anticipate that these will ultimately have an adverse impact on the overall achievement of the Project's Output and Result indicators and the Priority's Specific Objectives.

Specific issues identified by the Project Partners include:

- **IP issues impacting on the establishment of Collaborative Research Agreements and businesses' recruitment -** The Project's Partners notes that there were a number of protracted discussions with potential industry members in relation to background and foreground IP arrangements (being mindful of state aid implications), with the Collaborative Research Agreements[51] taking longer to agree than was originally anticipated. Indeed, as noted, one business that was initially interested in engaging on the project, ultimately took the decision to withdraw due to issues relating to the ownership of foreground IP emerging from the research;

- **Delays in the recruitment of PhD students and wider research staff** to support project delivery - Consultation with the Project's Partners indicate that there were delays in the recruitment of PhD students and wider research staff to support the delivery of the Renewable Engine project. The Project's Partners are of the view that this situation may have arisen due to two distinct, but interrelated demand and supply factors, including:

  - Firstly, the Project's Partners note that a number of different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the Renewable Energy sector. This inadvertently created significant demand within the market for these students at the same time, resulting in a shortage of available students and, by association, delays in recruitment;

  - Secondly, the Project's Partners suggested that interest in undertaking research as a career path (as a PhD student) may have been reduced as a consequence of relatively higher engineering

[51] The agreement between the industry and research partners outlining the roles and responsibility of the research team and the industry partner, research project brief, details on commencement and duration, conduct of the research project, match funding, IP agreements monitoring arrangements etc.

salary levels within the private sector and the fact that potential students maybe detracted from a research career due to increasing student costs/fees. Combined these factors may have served to reduce to pool/supply of potential PhD students.

- **Staff mobility issues** - Difficulties have been encountered in non-EU resident PhD students travelling outside their country of research residence. For example, a non-EU national with a visa to undertake research in a NI academic institute was unable to travel to the ROI area of the eligible region. The Project's Partners expressed concern that such issues could potentially be exacerbated following the UK's departure from the EU (following 'Brexit').

4.6 Best Practice and Learning

Key examples of best practice and learning that have emerged during the initial period of the project's delivery include:

- **Delivery of activities to enhance levels of knowledge transfer, PhD student development and create a 'Centre' ethos -** The Renewable Engine project has delivered a series of activities that have sought to enhance levels of knowledge transfer, PhD student development and create a wider 'Centre' ethos (as opposed to students working in isolation on individual research projects). Examples of these activities include:

  – Delivery of Research Colloquia at which PhD students have participated in a two-day away-day during which they were required to present the progress of their respective research projects engage in team-building activities and problem-solving group projects
  – The establishment of a project management and team communication platform (using the 'Basecamp' software), which provides an opportunity for research staff to contribute to research projects and papers (which they are not primarily responsible for) from their inception;
  – Delivery of 'Group Therapy' sessions and establishment of social media groups where students are provided with the opportunity to discuss issues that they are encountering on their respective projects in order to identify potential solutions

- **Facilitation of tours** of the Project's Partner's respective institutions to highlight their respective skills and expertise, encourage wider collaboration and sustainability beyond the Programme period;

- **Rotation of quarterly progress meetings** at each of the Project's Partner's respective institutions to stimulate a joint sense of project ownership and greater levels of transnational interaction; and

- The project securing a broad gender balance in PhD students, which the Partnership notes is not reflective of the wider trend within the Science, Technology, Engineering and Mathematics subject areas.

4.7 Synergies between Projects funded

Given their focus on the renewable energy sector, the Project's Partners note that they have undertaken a number of meetings with the Project Managers of the SPIRE 2 and Bryden Centre projects to discuss project progress, share knowledge to address project-specific issues and identify further opportunities for collaboration. According to the project partners, by working with the manufacturing sector in the development of renewable energy products, the partners will be developing manufacturing capacity which may be needed for the delivery of projects such as SPIRE, the Bryden Centre and CASE. For example, given the focus of both projects to undertake research in the area of anaerobic digestion, the Renewable Engine's and Bryden Centre's project managers are in the process of identifying potential project synergies and opportunities to collaborate.

It is further noted that a number of PhD students from the Renewable Engine project attended the Bryden Centre Summer School at UHI during 2019 which served to (inter alia) enhance the levels of industry engagements, provide an overview of the project's research and capabilities.

Renewable Engine, SPIRE 2 and the Bryden Centre are working closely together with the Advanced Forming Research Centre (AFRC) at University of Strathclyde, Energy Technology Partnership (Scotland) and CASE (NI) in delivering regular joint showcasing and presentations of the PhD work in renewables and energy storage at events such as All-Energy Conference and Exhibition in Glasgow. The event in 2019 was deemed by the Project Partners to have been a major success with several Renewable Engine presentations being made in collaboration with both Bryden and SPIRE 2. Preparations are underway for the Innovation Zone showcase at All-Energy in 2020.

Additionally, it is anticipated that companies from the project will progress to Invest NI programmes assisting companies along the innovation escalator; thus, businesses will be more aware of funding opportunities and the methods of working in this arena.

4.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the Renewable Engine project's collaborative and partnership working including:

- The effectiveness and added value of the Renewable Engine project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

The Renewable Engine project partners suggest that the INTERREG VA Programme has presented an opportunity to create a new cross-border R&I supercluster for renewable energy manufacturing. The intention is to utilise cross border collaboration to increase the level of R&I competence and activity across the programme area in a strategic way designed to contribute towards the development of a more competitive, high value-added economy. Therefore, according to the project partners, cross border collaboration is the key enabler for 'Renewable Engine', making available innovation support, technology demonstration, product design/development expertise and lab facilities, which would otherwise not be available jointly across the programme region.

'Renewable Engine' integrates joint development, implementation, governance, staffing and financing, which is core to the planning, deployment and management of the project on a cross border and transnational basis. At the strategic level, the project partners are of the view that 'Renewable Engine' is serving to strengthen territorial cohesion through an integrated approach, with the potential to reduce funding fragmentation by bridging the gap between the strategic and operational levels.

They suggest that the project's operational model is defined so that industry can access the most appropriate staff and R&I infrastructure regardless of jurisdiction.

In terms of specific collaborative actions, the project partners note the following:

Joint Development	'Renewable Engine' involves a strong cross border partnership incorporating research institutes with demonstrated excellence in advanced manufacturing and the renewable energy sector. Working as a cross-border partnership, 'Renewable Engine' has been developed and agreed to ensure it best meets the recognised engagement needs of industry across the region. As part of the preparatory phase of the project, the partners engaged in direct primary research and consultation with industry across the region. Companies consulted at that stage included Edge Innovate, Terex, Sandvik, Powerscreen, SpecDrum, DMAC Engineering, Eurospring, Nugent Engineering, Williams Industrial Systems, Steelweld Fabrications, McCloskey International, Kingspan and Clarehill Plastics. This business intelligence served to shape the project concept to address existing market failures and emerging opportunities. This activity was followed by a series of cross border partner planning workshops and stakeholder input sessions.

Joint Implementation	The project partners state that 'Renewable Engine' is making available innovation support, technology demonstration, product design/development expertise and lab facilities which would otherwise not be available jointly across the programme region. According to the project partners, the combination of facilities and the associated experience and knowledge the partnership brings allows for a focused but comprehensive range of technology disciplines to be addressed with particular expertise being held by the partnership in the disciplines of additive manufacturing, renewable energy technologies and intelligent manufacturing systems. The project partners are of the view that this 'supercluster' approach which is encouraging an open system of innovation that is offering innovative enterprises the potential to externally source and connect with a wider variety of relevant expertise will lead to improvements in businesses' capability and capacity to: • Access new technologies, intellectual property and ideas from external sources; • Integrate and exploit these external elements into innovative new products, processes and service developments; • Collaborate on innovation with suppliers, customers, industry networks and competitors; and • License-out to gain value from ideas and technologies that do not fit the core strategy of the company. In addition, the project partners note that an International Stakeholder Group has been established to further enhance their understanding of the needs of and opportunities within the renewable energy sector. Its members include leading international and regional academics and industrialists in renewable energy.
Joint Staffing and Financing	Collectively the partnership has areas of specialism covering renewable energy, additive manufacturing, and intelligent manufacturing systems. Through 'Renewable Engine' the delivery partners are in a position to pool their significant resources and expertise on a cross border basis and provide services, skills and access to facilities which would otherwise not be available. According to the project partners, project staff (e.g. Principal Investigators, R&I Co-ordinators and Post-doctoral researchers) are fully accessible across the entire region and are being deployed (either physically or through online collaboration) to service industry needs as needed. That is, industry can access the most appropriate staff and infrastructure regardless of jurisdiction.

The Renewable Engine project partners consider that considerable added-value has been created as a result of the cross-border working, and note the following:

- They are making progress in creating an internationally recognised R&I cluster in the renewable energy manufacturing sector (that would not be achieved by smaller initiatives in the same area of R&I);
- The project is facilitating the development of working relationships and interworking between the project's partners and it is anticipated that the development of these relationships will be sustained following the project period;
- Cooperation in complementary activities is reducing the potential for duplication of services and facilities across the border region, enabling participating actors to capture knowledge and spillovers that would otherwise be lost, and is reducing duplication in R&D infrastructure investments and is instead exploiting economies of scale in R&I activities. The project partners are of the view that this will ultimately lead to faster development and market launch of new products and services; more diversity brought to innovation resulting in the identification of more opportunities for growth; and improved success rate of new products and services by making the innovation process stronger.
- The project is underpinned by an 'Open Innovation' ethos. The project partners suggest that it is increasingly difficult for industry to innovate and grow in isolation and enterprise need to engage with different types of partners to acquire ideas and resources from the external environment to stay ahead of the competition;

- They anticipate also that improved access to the UK Catapult Centres (through the University of Strathclyde) for NI and ROI companies will result in better working relationships being developed and greater knowledge exchange occurring;
- The partners consider that there will be a general improvement in the quality of R&I output as a result of a better ongoing working relationship between industry and academia; and
- An outworking of the project will be the development of PhD qualified researchers with skills and knowledge directly applicable to local industry.

4.9 Impact on Business and Industry

This section considers the impact of the Renewable Engine project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

Notwithstanding this, anecdotal feedback from the Project Partners suggests that the project has served to (at least in part):

- Identify wider research and business development opportunities. For example, it was noted that, as result of their interaction on the project, a number of Scottish businesses are currently exploring the potential to use locations on the Island of Ireland as potential test centres.
- Increase businesses' knowledge and understanding of the benefits of working collaboratively with academic institutions which may result in the development of longer-term working relationships;
- Linked to the previous point, the Project Partners note that businesses have developed a greater understanding of the respective research strengths and capabilities that exists within the academic institutions;
- Increase academia's understanding of the needs of industry; and
- Support businesses to take forward commercially focused R&D which may not have been undertaken due to their capacity and capability.

4.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the Renewable Engine project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

4.10.1 EU2020 Objectives

Through the potential development of renewable energy technologies emanating from the research, the project offers the potential to contribute to a number of key objectives including:

- 3% of the EU's GDP should be invested in R&D;
- The 20/20/20 Climate/Energy targets should be met (including an increase to 30% of emissions reduction if the conditions are right)

Furthermore, the subsequent creation of outputs (e.g. renewable energy products and services) emanating from the research offers the potential to contribute to the target to ensure that 75% of the population aged 20 to 64 should be employed.

4.10.2 The Atlantic Strategy

The Evaluation Team notes that elements of the Renewable Engine project's research (e.g. Development of lightweight roto-moulded multi-layer structures) is overtly focused on developing offshore energy generating technologies and hence offers the potential to contribute to key themes underpinning the Atlantic Strategy including the 'Reducing Europe's Carbon Footprint' theme which advocates that steps should be taken to exploit the Atlantic's powerful waves and strong tides to generate renewable energy.

4.10.3 The Horizontal Principals

The Renewable Engine project partners consider that the project will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

Sustainable development	The project partners suggest that Sustainable Development is core to each organisation and integral to the delivery of their services, and note that the Renewable Engine project has at its core the aims and objectives of achieving a sustainable economy, using sound science responsibly, promoting good governance, economic prosperity for our region, enhancing the social opportunities for our communities and living within environmental limits. Socially, the project aims to develop and enhance opportunities for residents of the eligible region and involve communities in the decision-making process. The project partners anticipate that this will be seen through investment in resources and infrastructure, improving access to services and working to create opportunities in education and employment. The project aims to develop services for industry to bring new products forward thus helping to develop an outward-looking region aware of the international opportunities in the RE market and the importance of the region's natural capital and environmental limits. The project partners suggest that it is likely that these products will decarbonise energy and waste infrastructure, and will have an impact on the implementation of affordable clean energy both in the region and those to which new technology is exported. The project partners see opportunities in energy generation, management, storage and resource efficiency. To deliver objectives in these areas, equipment for recycling, waste management and energy generation from waste materials will be researched and investigated for manufacture. The project partners envisage that this will enhance the project's credentials in the area of assisting the avoidance of pollution of air, land and water and assist our society in living within environmental limits.
Equal opportunities and non-discrimination	According to the project partners, six principles underpin the design and implementation of Renewable Engine project: Promoting accessibility, valuing cultural diversity, promoting participation, promoting equality of opportunity, promoting inclusive communities and reducing exclusion. SWC as lead partner has attended SEUPB's Mainstreaming Equality Training and has stated that it will comply fully with legal obligations on equality and non-discrimination in conjunction with key regional legislation; Northern Ireland (Section 75 of the Northern Ireland Act 19986, Equality Act 2006, Employment Equality Act 2006, Disability Discrimination Act 1995), Ireland (Employment Equality Act 1998, Equality Act 2004, Equal Status Acts 2000-4) and Scotland (Equality Act 2000, Gender Recognition Act 2004). The project partners note that accessibility for persons with disabilities will be taken into account when organising venues for training, meetings and events to ensure all have equal opportunity to access and fully participate (ramps, lifts, and toilets). In addition, they state that, if required, information materials including brochures, website etc. will be adapted to the special needs of certain categories. Publicly available documentation including public procurement documents and job descriptions will also respect the principles of non-discrimination by using language

	and selection criteria that avoid exclusion of any particular group. Further, to promote a transparent recruitment process all jobs have been advertised outside of the partner organisations and a representative interview panel has been used for selection. Equality of opportunity has also been supported through the project's open call process for recruiting industry partners. This process has included public advertisement, application and selection based on established criteria to ensure the local industry have equal opportunity to apply. The PMT has also used an Equality Monitoring Form to determine if each research project has given due regard to equality and to allow decisions to be made about any actions which could improve equality of opportunity.
Equality between men and women	The project partners note that the integration of gender perspectives has been taken into account and promoted throughout the preparation and implementation of the project. Renewable Engine has promoted equal opportunity for women and men in the management arrangements of project, recruiting a gender-balanced Project Board and Project Management Team. To promote gender equality amongst the research personnel, women researchers have been recruited. Further, US as WP3 lead has ensured that both male and female experts in the Renewable Energy and Advanced Manufacturing sectors are represented in the International Stakeholder Group.

4.10.4 Contribution to Other Strategies

The Renewable Engine project partners suggest that by enhancing the R&I capacity of industry and academia, the project will support a number of local and regional strategies and initiatives across the programme area, including the following:

Northern Ireland	• **Northern Ireland Innovation Strategy 2014-2025 -** Renewable Energy, R&I and collaboration are consistent themes throughout the Northern Ireland Innovation Strategy 2014-2025. A key objective of the strategy is to encourage more businesses to innovate by engaging in business to academia and business to business collaboration. Renewable Engine will increase both forms of collaboration through the provision of PhD research activity to 8 industry partners and further through the development of a unique cross-border 'Research Supercluster' involving high calibre research and industry partners who will engage in open innovation to capitalise on opportunities for innovation. Renewable Engine will further complement the strategy by focusing on resources where there is the greatest opportunity for high-value growth and export, particularly sustainable energy as a smart specialism priority for Northern Ireland. • **The Northern Ireland Economic Strategy -** The key drivers of this strategy are considered to be innovation and R&D. It is anticipated that Renewable Engine will support the economic priorities in The Northern Ireland Economic Strategy, by facilitating businesses to increase productivity through the provision of direct research support, financial grants and access to world-class expertise and technology, with the aim of exploiting the global opportunities in energy generation, storage and connectivity, which in turn will help to rebalance the NI economy.
Scotland	• **Scottish Economic Strategy 2015 -** The Scottish Economic Strategy has R&D and innovation woven into its strategic objectives. It seeks to foster a culture of innovation by supporting high impact world-class research and promoting the development of innovative businesses actively commercialising of R&D. It is envisaged that Renewable Engine will improve levels of commercialisation activity for the industry partners in line with the objectives in this strategy, by developing an overarching framework for intellectual property including IP identification, protection and management. • **Renewing Scotland – The Governments Programme for Scotland 2015-16 -** Fostering a culture of innovation and research and development is a fundamental component of the Scottish Governments Programme. The strategy emphasises the importance of maintaining higher education R&D and 'world-leading' quality of research according to the Research Excellence Framework. In line with the

	strategies objectives, Renewable Engine will seek to exploit the world-class research, supporting businesses to commercialise on their innovation activity through university and business collaboration.
Ireland	• **Innovation 2020 Excellence Talent Impact -** The Irish Innovation Strategy has a number of targets to reach by 2020 including; increasing gross expenditure on R&D to 2.5% of GNP, increasing the number of enterprise R&D performers by 15% and securing €1.25bn from Horizon 2020 to support innovation activity. Through both the financial and non-financial support provided by Renewable Engine, it is anticipated that enterprises will have increased their capacity to engage in R&D activity and their ability to secure funding from European research and innovation instruments. • **Enterprise 2025 -** A core component of Irelands Enterprise Strategy is 'Enterprise Resilience', building supportive systems to pursue new opportunities across a range of sectors. The strategy encourages enterprises to invest in R&I and to stimulate greater cross-border collaboration between enterprises and HEIs with the aim of creating clusters of sustainable competitive advantage in key 'transforming sectors' including green technologies. It is anticipated that Renewable Engine will strengthen interregional and cross-border innovation systems, promoting the development of a cross-border 'Research supercluster' to leverage enterprises ability to engage in R&I, in turn promoting the development of innovative products and new ways of doing business.
Other	• Achievement of the Europe 2020 Strategy for Growth by developing an economy based on knowledge and innovation in growth sectors such as renewable energy.

In summary, the Evaluation Team is of the view that the Renewable Engine project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

4.11 Barriers to Cross-Border Cooperation

The Renewable Engine project partners have not identified any barriers to cross-border cooperation that the priority axis is not addressing.

4.12 Exit Strategy

An important objective of 'Renewable Engine' is to maintain a 'world-class' R&I service in the cross-border region post the INTERREG VA funding period. The project partners note that sustainability will be the responsibility of the programme board and Programme Director and will be an agenda item at the quarterly meetings.

The project partners further suggest that:

- The R&I outputs from Renewable Engine will result in economically advantageous outcomes for the businesses supported by the outputs and results being incorporated into their core businesses.
- They anticipate that many of the PhD students will gain employment with their host company.
- The project's infrastructure will be financed from a business model that will include income from IP developed over time and future research funding. As a continuing partnership, the project partners suggest that they will be engaging with the participant companies to bring forward further work supported by national and international research and innovation programmes. The partners intend to assist enterprises with applications for new funding.
- Towards the close of the programme, research staff will be given individual R&I external funding targets to maintain activities following the funded project.

5. BRYDEN CENTRE FOR ADVANCED MARINE AND BIO-ENERGY RESEARCH

5.1 Introduction

This section of the report considers the Bryden Centre for Advanced Marine and Bio-Energy Research (Bryden) project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry relevant research and innovation capacity across the region.

5.2 Project Overview

5.2.1 Background

The Bryden Centre for Advanced Marine and Bio-Energy Research (Bryden) project partners consider that the eligible region has many geographic, economic and demographic characteristics that when combined represent a unique opportunity for the development of renewable technologies and should provide a distinct competitive advantage in a global marketplace. These include the tidal power sites at Strangford and the North Antrim Coast, the offshore wind activity in Western Scotland, the potential for wave power generation in Donegal, and the nascent anaerobic digestion industry driven by the regional agri-food industry and need for distributed energy. The combined region also has truly world-leading research taking place within its research institutions.

However, a number of challenges have prevented the regional industry from fully capitalising on this opportunity. Foremost among these is the profile of the regional industry, with companies typically being small- or micro-sized enterprises. As is true for all industries, small enterprises in the renewables sector struggle to dedicate the resource needed to innovate. This is exacerbated by a lack of funding for research and innovation that would allow industry and research partners from across the region to collaborate on early-stage innovative concepts. In addition, there is a recognised gap between outcomes from existing research projects and commercialisation, 'the valley of death', that is indicative of industry and University partnerships not maximising the outputs of early-stage collaborations. The final aspect of this is a lack of critical mass of highly qualified scientists and engineers capable of translating research into commercial success within these companies. The Bryden project aims to address these challenges.

The project partners have identified other problems that the marine renewables and bio-energy sectors face on a cross-border, interregional basis, including:

Table 5.1: Problems facing the marine renewables and bio-energy sectors

	Marine Renewables	**Bioenergy**
The issue or problem that may require action	Achieving a levelised cost of energy	Optimising value for supply chain recipients
The underlying drivers of the problem?	• All off-shore renewables generation is more expensive than onshore alternatives/equivalents and conventional sources • Security and consistency offered by marine renewable energy has been undervalued by network operators and commodity markets • Constrained networks and grid infrastructure	• Techniques and technologies required to optimise bioenergy systems that suit the feedstock availability • Lack of understanding whole life cost and benefits understanding encompassing materials sourcing, refining, recovery and delivery of bioenergy • Feedstock industries are not engaging as partners
Who is affected, in what ways, and to what extent?	• The economic development of the supply chain is being constrained; • Economics restricting technology providers from presenting business cases supporting innovation; • No diversification from the traditional industry; • Support services commercial activity is restrained.	
What are the negative effects that result?	Levels of marine renewable investment, technology development rates and project realisation, significantly lags the quantity and quality of the energy potential available	Undervaluation of bio-ecology, physio-geographic and socioeconomic characteristics within the INTERREG VA area bioenergy supply chain

Bryden seeks to de-risk applied research that is generally far from the market, giving businesses within the region the first-mover advantage, allowing the creation of new disruptive technologies. Related needs the project will address include, the need to:

- Accelerate economic growth through the generation of advanced technology, information and knowledge;
- Address low levels of BERD and HERD;
- Address weak regional R&D capability amongst businesses;
- Stimulate cross-border industry-academia linkages and knowledge/technology transfer activity;
- Enhance the absorptive capacity of businesses;
- Address skills shortages relating to industrial R&D;
- Address market fragmentation in the regional renewables sector.

5.2.2 *The Project*

The Bryden project has seven project partners including Queen's University Belfast (as Lead Partner), University of Highlands and Islands, Letterkenny Institute of Technology, Ulster University, Agri-Food and Biosciences Institute, Donegal County Council and Dumfries and Galloway Council[52]. Prior to the introduction of the project, the project partners had been working together for a period of 4-5 years on an innovation centre concept that aimed to address market failures in the eligible region. The project partners suggest that their partnership has been helped by an alignment of cultures and competencies and a desire to build on the expertise amongst the project partners in order to create a lasting legacy for the renewables sector, and cross-border academic/industry collaborations.

The project partners anticipate that Bryden will create a 'virtual competence centre' that will support industry-led applied/pre-commercial collaborative research (at Technology Readiness Levels - TRLs 2-6) on a cross-border, interregional basis that is focused on two specific forms of renewable energy, which are considered to have the greatest sustainable potential and widest applicability in the region:

1. Marine renewable energy; and
2. Bioenergy.

The project aims to build upon and considerably enhance existing research activity and capability in the region, and in particular that which is undertaken at the CASE Competence Centre, by facilitating a scale of activity and critical mass of expertise and knowledge transfer within the region that has not been possible to date, but which is anticipated to generate impact and added value on a comparable basis.

Using a Doctoral Training Centre model, it is anticipated that the Bryden project will recruit 34 PhD students and 5 PDRAs; each of whom will work with industry to produce industrially relevant research with the potential for commercial exploitation and resulting economic growth within the region.

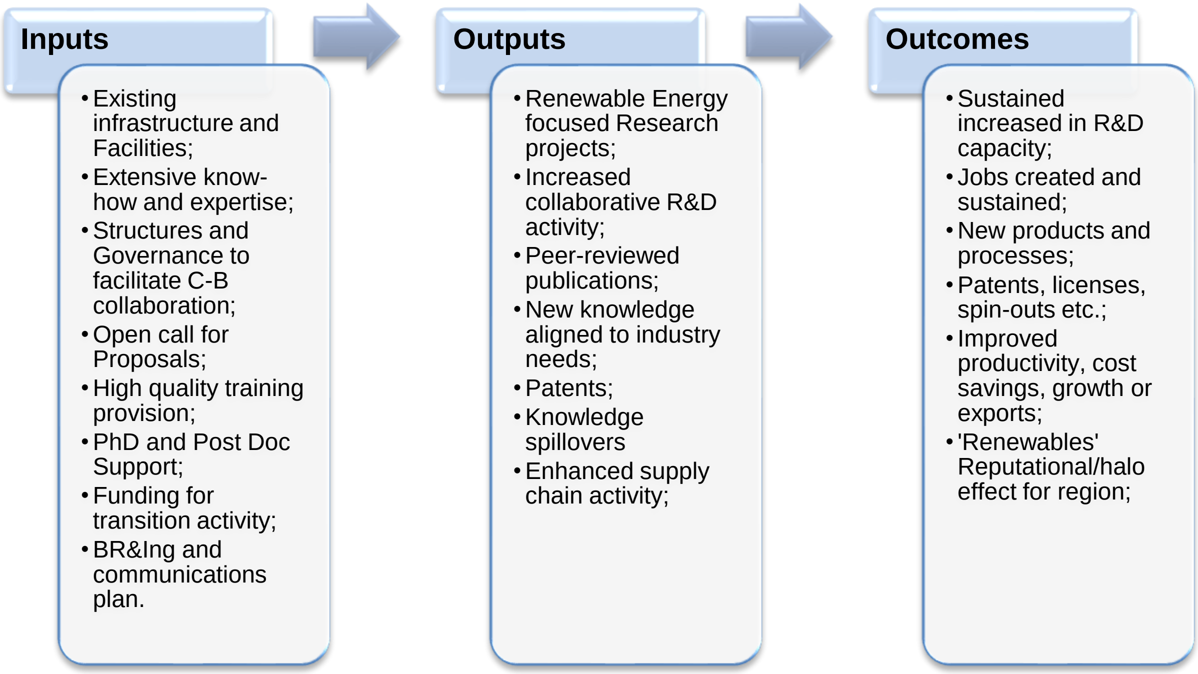
Bryden aims to provide a supportive interdisciplinary environment for students to carry out a challenging PhD-level project. It will provide engineers and scientists with the skills, knowledge and confidence to tackle the evolving issues and future challenges of the renewable energy sectors. It will act as a catalyst for bringing industry and academics together on a cross-border basis, create new working cultures, build relationships across universities and forge lasting links with industry.

Bryden's Vision is to *"provide the springboard to the growth of world leaders in the marine and bio-energy sectors in the region'. By bringing together industrial and academic partners, BRYDEN will deliver a step-change in the level of industry-informed research and innovation that the sector can capitalise on, and supply of doctoral-level scientists and engineers to enable sustained growth for years to come"*.

[52] It is anticipated that Dumfries and Galloway County Council and Donegal County Council will provide a conduit to connect Bryden to business enterprises and will support networking and dissemination of the project within their regions. This support will be provided as part of each County Council's delivery strategy as an in-kind contribution to the project and will not be remunerated.

It is envisaged that the Bryden project will employ the following logic model:

Figure 5.1: Bryden Project Logic Model



The model will be closely aligned with best practice in competence centre networks and will allow both clusters of companies and individual businesses to participate in applied research. Industrial partners will be involved in each individual research project, which, it is anticipated, will ensure effective Knowledge Exchange. All sizes of businesses will be encouraged to participate, but particular emphasis will be placed on the involvement of SMEs, who are anticipated to benefit from the outworkings of the research but also from networking, the formation of new partnerships and informal and formal knowledge transfer.

Figure 5.2: Bryden's Operating Environment

It is envisaged that businesses will benefit by gaining a deep knowledge of new technology or science, having time to assess it before (potentially) investing in its commercialisation. Knowledge and skills transfer will also occur as all 34 PhD students will work closely with industry.

Each PhD student will be co-supervised on a cross-border basis.

Whilst the specific scope of the research projects will not be known until they apply and are assessed as part of the suggested model, it is envisaged that the research undertaken might focus on areas such as:

- Ensuring that renewables can compete successfully, without subsidy, once external environmental costs and other contributions to social goals (e.g. access, security) are taken into account.
- Improved performance (and cost reductions), including conversion efficiency, reliability, durability and lifetime - helping to reinforce the role of renewable energy in a sustainable energy system.
- Advanced manufacturing techniques for components;
- Reduced material requirements, especially for toxic materials;
- Sustainable production processes that minimise life-cycle environmental impacts through manufacturing, use, recycling and final disposal;
- Improved methods for integrating renewable energy into buildings, electricity grids and other distribution systems.
- Developing ICT protocols that enable and optimise renewable energy availability and its integration into transmission/distribution infrastructure at the community, regional, national and transboundary levels;
- Socio-economic research aimed at developing effective policy measures that will encourage the deployment of renewables and enhance public acceptability of new energy technologies.

The Bryden project employs the following distinct and inter-related 'work package' delivery model, which was developed following the project planning phase and consultation with all partners who have informed its design:

Figure 5.3: Work Package Delivery Model

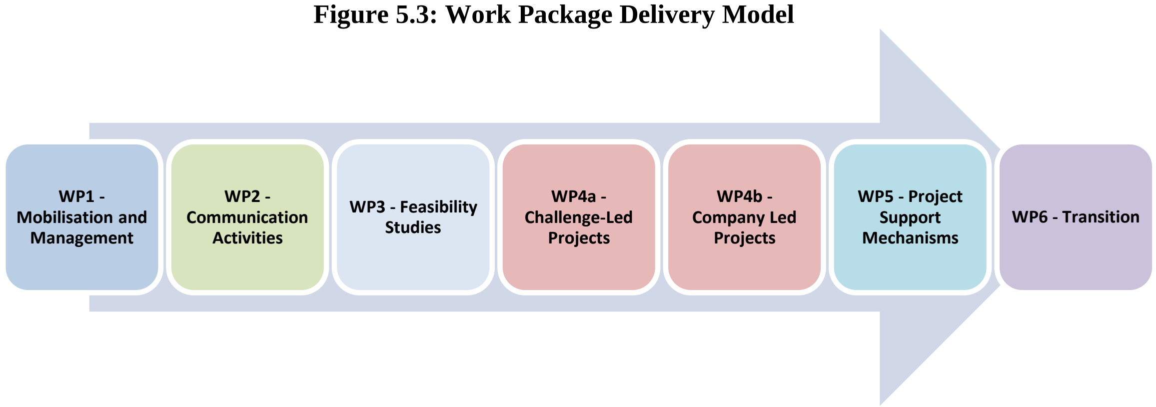


Table 5.2: Bryden Project Work Package Delivery Model	
Work Package	**Description**
WP1 Management	Robust governance will be employed by Bryden's Board (see Section 5.2.3). In terms of project selection, the Centre has adopted the following process: **Open Calls for Proposals** Bryden has advertised open calls for research project proposals using a wide range of media and direct consultation methods throughout the eligible regions. The calls have been focused on challenge led / sector-wide issues relating to marine and bioenergy, as well as inviting projects that concentrate on individual company issues. **Project Selection Criteria** Project selection criteria have been set by the SandC Advisory Panel and approved by the Board. Criteria for consideration are outlined in the Submission of Proposals section below. A standard evaluation form has been developed to include the criteria for review and a scoring mechanism has been designed and used in the Phase 1 Evaluation (SandC Advisory Panel).

<table>
<tr><th colspan="2">Table 5.2: Bryden Project Work Package Delivery Model</th></tr>
<tr><th>Work Package</th><th>Description</th></tr>
<tr><td></td><td>
Phase 2 evaluation (and Board Vote) has concentrated on areas of uncertainty/further information required following the Phase 1 evaluation process. Project proposers are asked to present to the Board to clarify or enhance their Phase 1 proposals.
Submission of Proposals (Challenge / Industry-led Projects)
Collaborations of companies and research institutions have been encouraged to submit Proposals for potential research projects to the SandC Advisory Panel / Bryden Director in the first instance at a defined deadline for receipt (defined in the call documentation). The Proposals must include a Project Champion from a company and an Academic Champion from the Research Institution and must meet the following minimum criteria:

Involve at least two enterprises from two of the eligible regions (or that the research work will take place within the eligible region);
Involve one or more PhD studentships;
Be between Technology Readiness Levels TRL2 and 6;
Be industry-driven thereby:

Evidence of industry involvement in the development of the proposals;
Involve at least one industrial partner (registered company of any size);
Industrial contribution should be at least 20% of the overall value of the project (expect this to be an ‘in-kind’ contribution);
Relate to the core research priorities at BRYDEN of marine renewable energy and/or bioenergy;
Has a potential viable pathway to commercialisation.

An acceptable level of innovation
Excellent standards of unique research outlined.

</td></tr>
<tr><td>WP4a Challenge-Led Projects</td><td>
WP4a will address marine and bio-energy sectoral-level grand challenges as identified and prioritised by industry, that act as a specific critical barrier that, if removed, would help solve an important problem that is stymying the adoption of renewable energy within the region, but also provide a high likelihood of global impact through widespread implementation.
These projects will be characterised by a focus/sector-wide issues relating to marine and bio-energy, rather than issues specific to a single or small number of companies. The review process will ensure these projects meet the specific additional criteria of being:

A challenge that faces multiple industry stakeholders;
Capable of being significantly addressed by Bryden research;
Involving the input of more than one of Bryden’s research partners; and
Capable of leading to a significant increase in the capability of the regional renewable energy sector.

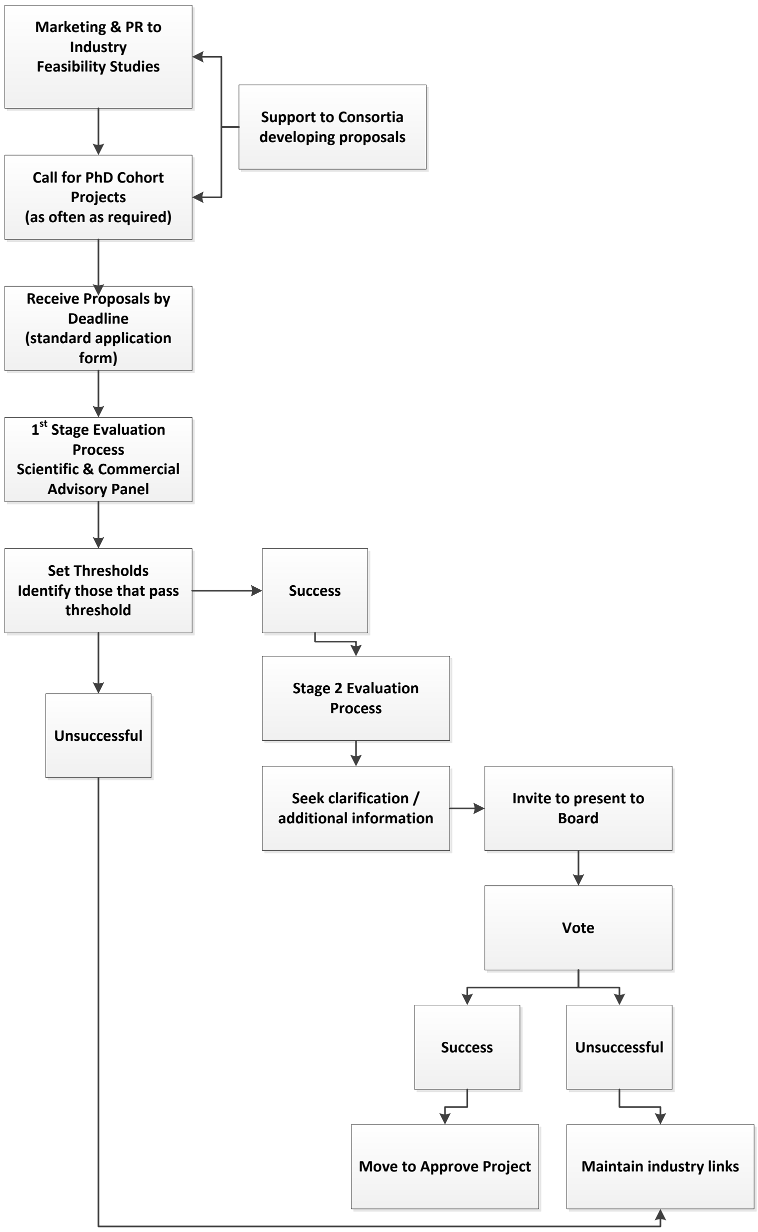
The Challenge-Led Projects will consist of one or more PhD studentships that will be supervised by at least two of the BRYDEN research organisations, and may also be augmented by research carried out by the Thematic Managers or Project Managers.
It is envisaged that the outworkings of such research will bring considerable economic and commercial impacts to the region, as well as many positive social and environmental impacts.
</td></tr>
<tr><td>WP4b Company-Led Projects</td><td>
Research projects taken forward under WP4b are likely to involve individual (or small groups of) PhD studentships, who will take forward a research project led by an individual or small group/cluster of businesses on a cross-border basis.
Thematic areas that were identified by industry representatives during the development of the project included:
<table>
<tr><td>Marine Renewable Energy</td><td>Overarching Sub-Theme: Reducing the Levelised Cost of Energy</td><td>Advanced Design and Manufacturing
Modelling/Resource Assessment
Environment/Marine Life/Habitat
Biofouling
Foundations and Deployment.</td></tr>
<tr><td>Bio-Energy</td><td>Sub-theme 1: Bio-resources</td><td>Algal biomass;
Other non-food biomass sources;
Waste Heat Recovery.</td></tr>
</table>
</td></tr>
</table>

Table 5.2: Bryden Project Work Package Delivery Model

Work Package	Description

	Sub-theme 2: Biogas Utilisation	• Grid integration; • Dual Fuel Vehicles;
'Cross-cutting' Themes		• Economics; • Supply chain; • Community/localised energy systems; • Life Cycle Analysis;

Each of these potential research areas is considered to have high economic and commercial potential. However, each potential project is required to apply formally to Bryden for support and would be assessed by the Bryden Scientific and Commercial Advisory Panel and Board using a 2-stage evaluation process, as follows:



Whilst yet to be finalised, selection criteria might include:

- Project size
- TRL level
- Proposed project plan
- Level of cross-border industry engagement
- Level of risk (technical, delivery, cost, completion etc.)
- Potential strategic (inter-regional) impact

<table>
<tr><th colspan="2">Table 5.2: Bryden Project Work Package Delivery Model</th></tr>
<tr><th>Work Package</th><th>Description</th></tr>
<tr><td></td><td>Potential to deliver business/economic benefits for businesses within the region, in terms of product innovation, export growth etc.
Appropriate demonstration of the need for financial assistance to satisfy additionality requirements;
Evidence that the project is additional to any existing work
The degree to which a participant's commitment has been demonstrated
Clear demonstration of a cross-border element that could not be taken forward under existing structures within the three jurisdictions (to avoid displacement).
Ambitious and novel research proposals addressing new concepts and techniques, and those with the potential for significant commercial, scientific or user impact will be particularly encouraged. Interdisciplinary proposals will also be encouraged as it is recognised that many of the most pressing 'renewables' research challenges are diverse and interdisciplinary in nature.</td></tr>
<tr><td>WP3 Feasibility Studies</td><td>It is anticipated that a small number of proposed research projects may require some additional scoping before they can be considered for selection under WP4a and WP4b. This activity might include assessing the technological feasibility of an outline project proposal, its market applicability or scale of market opportunity, or identifying suitable academic resource from across the five research institutions for projects brought forward by the industry stakeholders.

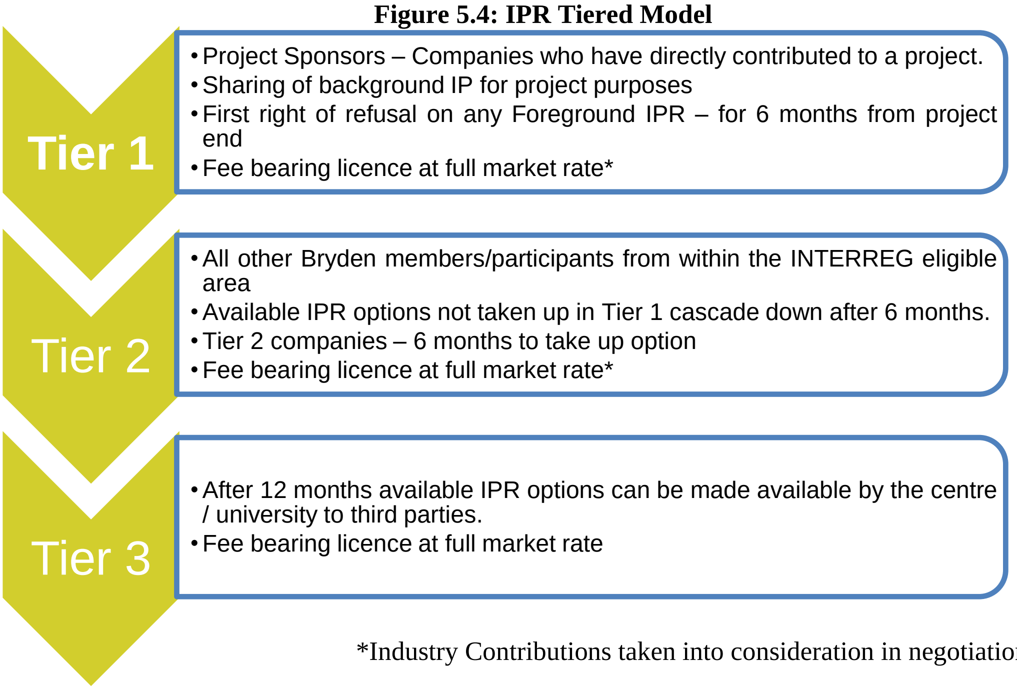
This strand of activity is anticipated to allow for PDRA resource to be allocated to undertake such activity. Such a resource will be provided over a short period of time (<6 months per feasibility study).</td></tr>
<tr><td>WP5 – Project Support Mechanisms</td><td>It is anticipated that the programme of 'studentship' activity will go beyond the boundaries of a traditional industrial PhD programme. It is envisaged that Bryden will leave a lasting legacy upon the region through the development of world-class leaders of the future who will have the skills to identify solutions to the major challenges that impede the adoption and rollout of renewables. This enhanced PhD offering will provide students, not only with the necessary scientific skills and knowhow but will also:
Adopt the principle of cohort training (through a summer school format, hosted in each of the three jurisdictions, alternating on an annual basis) and individual training in areas of:
Business management and entrepreneurship skills e.g. financial planning; market research etc.;
Personal skills development e.g. research methods, dissertation planning, scientific report writing, ethics, presentation skills, time management;
Technical skills e.g. statistical analysis, ICT.
Provision of 'on-off' training to the PhD cohorts as and when the need arises or, the opportunity presents itself – this training might involve technical skills that are transferable in the marine renewable and/or bio-energy sectors;
Extensive industry 'onsite' working/internships;
Secondment opportunities with 'associate partners institutions' to add value and breadth to the PhD experience;
Dedicated support and mentoring from a PDRA;
The ability to access expertise from throughout the region through cross-border/interregional co-supervision.
This work package will also offer additional support to industry stakeholders through the provision of project-specific 'route to market' professional services advice e.g. relating to IP, commercialisation opportunities and finance raising.</td></tr>
<tr><td>WP6 - Transition</td><td>WP6 will be realised in two principal ways:
A series of Knowledge Exchange placements, in which PhD level graduates will take up short-term employment with an industrial partner to support the translation and embedding of innovative technology or practices into their business.
Transfer of formal intellectual property from Bryden research organisations to industrial partners through licensing or assignment of IP.
<u>Knowledge Exchange Placements</u>
In enabling knowledge transfer into SMEs, the project partners suggest that it is important to recognise the challenges the companies will have in integrating innovative concepts into their business. The absorptive capacity of a company can be limited by staffing levels, financial resources, and skill levels of existing technical staff. Successful schemes, such as Innovate</td></tr>
</table>

Table 5.2: Bryden Project Work Package Delivery Model	
Work Package	**Description**
	UK's Knowledge Transfer Partnership programmes, have addressed this challenge by making people exchange a key component of knowledge exchange. Building on that approach, Bryden will provide for at least 10 KE Placements. During the latter stages of Bryden, it is anticipated that a call will be released to existing Bryden industrial participants for KE Placement programmes. Each application will identify a Bryden technology or practice that the company is seeking to integrate into its commercial operations. The company will also provide a rationale for needing to employ a PhD level graduate to help integrate the technology into their business, citing their current capacity for innovation projects, and a plan to sustain the new commercial practice beyond the KE Placement. At least 10 awards of up to approximately £12.5k each will be available during the Bryden project (towards 100% of the salary cost of a post-award PhD graduate placement for a 3-month period). The awards will allow the company to recruit a PhD level graduate, most likely but not necessarily from Bryden Cohort 1, to work on commercial integration of the technology or practice. The £12.5k award is expected to allow the employment of a PhD graduate for 3 months. The company will be able to augment the award to increase the duration of the placement, or to allow for an increased resource available to the recruit during the placement. In order to ensure optimal delivery of the KE Placements, the Bryden Director will seek to commence a small number of pilot KE Placement programmes in approximately month 33 prior to the completion of the 1st Cohort of Bryden PhD students. To enable this, companies will be able to recruit PhD students that have not carried out a Bryden PhD, but that has been working in a research area that falls within Bryden themes. The technology or practice that the company hosting the KE Placement aim to commercialise must also align with the Bryden aims. The delivery of these pilot KE Placements will ensure that the projects that commence following the completion of the 1st cohort of Bryden PhD students in approximately month 46 will be managed in line with established practice. The Bryden Scientific and Commercial Advisory Panel will assess applications, and make recommendations to the Bryden Board on which should be funded. Applicants for projects approved by the Bryden Board will be notified by the Bryden Director in an award notification letter. The successful companies will be required to ensure their project is compliant with State Aid regulations. It is expected that the majority of awards will be compliant through the *de minimis* exemption. Projects that do not meet this exemption will require the company to make an additional contribution to the project to ensure the overall intervention rate is compliant with State Aid regulations. The successful companies will be required to complete an end of project evaluation report, which will be provided to the Bryden Director. <u>Intellectual Property Transfer</u> A key anticipated outcome of the Bryden project will be increased know-how amongst participating industrial partners, as collaborating on the Challenge-led and Company-led projects is envisaged to introduce them to innovative practices that may be applied in their businesses. However, it is also expected that more formal transfer of intellectual property (IP) will occur. The research partners in Bryden have developed experience in the commercialisation of academic research into practice, as demonstrated by indicators such as the Impact Case Studies of REF 2014, and reports from the Higher Education Statistics Agency on Licensing and IP Revenue. The IP transfer approach of the Bryden project has been developed based on that experience. The research partners will make available their commercialisation support staff to the Bryden project in order to ensure the Bryden IP portfolio is managed in line with established best-practice. The commercialisation professionals of the research organisations will cooperate in the management of the IP transfer. The time contributed by the research institutions to the IP Transfer component of WP6 has not been costed into the Bryden Project, and will be made as a contribution in kind. It is estimated that approximately 25% of studentships will lead to the filing of a priority patent application, most likely with the UK patent office. Budget has been included in the Bryden application to cover the costs of these initial filings. In some cases, in order to successfully achieve commercialisation of patented technology, it may also be necessary to obtain the services of third–party consultants in carrying out market evaluations or route-to-market assessments. Therefore, budget has also been included for such work. In seeking to engage the external organisation to deliver this work, the Bryden partners will follow appropriate procurement practice to ensure the appointment of suitably qualified organisations, and high value-for-money.

Table 5.2: Bryden Project Work Package Delivery Model	
Work Package	**Description**
	When a potentially patentable concept is developed in a Bryden project, the researchers involved in the work will notify their host institutions using that organisation's protocol. The researchers will also notify the Bryden Director of the development. The Bryden Director, in consultation with the Scientific and Commercial Advisory Panel, may choose to fund the cost of filing a priority patent application on the technology. The process will be managed by the host research institution. The commercialisation office of the host organisation, in collaboration with the other research partners, will then pursue commercialisation of the technology.
WP2 Communications	Dissemination activity will be embedded from the earliest opportunity, as it is considered vital to the Centre's sustainability. This WP will deal with the mandatory communications requirements and will involve the publication of a project marketing and communications plan. The dissemination of the research outputs through the peer-reviewed journal and conference publications will form a key aspect of the strategy, but it will also incorporate innovative methods, such as inclusion on industry-relevant websites, video, and conferences. Where a student's work is published, this will include an acknowledgement of the INTERREG support. A key focus of the strategy will be upon demonstrating the contribution that the research has made to society and the economy therein. A key channel that is anticipated to be explored is the development of future Horizon 2020 bids, utilising the new cross-border relationships that have been developed and the out-workings of the research undertaken as a foundation. In doing so, it is likely that facilities such as the EEN profile search and alert service will be extensively utilised to identify suitable additional academic and industrial partners.

To address State Aid considerations, funding under this project will largely (with the exception of support under 'WP6') only be available to the research institutions. In order to ensure compliance, agreements with industry collaborators will provide that the research institutions will own the results and associated IP created as a result of their activities in the project. Any participant company that wishes to exploit any IP developed in this way will be required to obtain a fee bearing licence at full market value less any contribution that they have made to its development[53]. It is anticipated that any IPR that is generated will be accessed on a tiered model as outlined below. This is similar in practice to the existing, and accepted competence centre model.

Figure 5.4: IPR Tiered Model



*Industry Contributions taken into consideration in negotiation

[53] The project partners note that the arrangements for IP were agreed between the project partners in consultation with industry partners. It is expected that most projects will not include access to IP for the industry partners at anything other than an open-market rate. It is suggested that this will mean that the projects will not be subject to State Aid restrictions, and therefore will not require a financial input from the company. The project partners consider that this is essential to allow the inclusion of small enterprises that are new to research and innovation activity to the project.

5.2.3 Project Management

Centre governance sits between the Project Partner's own specific corporate (or organisational) governance and the specific project management arrangements for the individual research projects. The main activities of the Centre's governance relate to:

- Centre/Programme direction;
- Project ownership and sponsorship;
- Ensuring the effectiveness of project management functions; and
- Reporting and disclosure (including communications).

There is a three-tiered governance system, which includes:

1. A Scientific and Commercial Advisory Panel;
2. The Centre Board; and
3. A high calibre management team.

Scientific and Commercial Advisory Panel	The Bryden Scientific and Commercial Advisory Panel (SandC Advisory Panel) provides overarching advice to the Centre Board and Management team. The Panel is made up of key international stakeholders from industry, academia/research organisations, policymakers, legislators, trade associations, business support and other funding bodies and third sector associations (e.g. community groups) who have a track record in driving research and innovation in the marine renewable and bio-energy fields. A representative from SEUPB has been invited onto the Panel as well as representatives from Competence and Technology Centres (where there is an existing critical mass in the region). The SandC Advisory Panel has been established to provide (amongst other things) advice and guidance on a wide range of topics including regional nuances, technical developments, policy and legislation etc. The Panel is also involved in setting the research agenda for the Centre and has elected the Bryden Board. Both the SandC Advisory Panel and Board appointments were by invitation only and subject to specific terms of reference. The Panel also plays a role in informing project selection criteria.
BRYDEN Board	The Centre is hosted by the 5 research institutions but is under the management and control of the Board. This aims to guarantee independence from any one institution. The Board has ultimate responsibility for oversight of Bryden's operations and will ensure delivery of the Centre's vision. The Board role includes establishing detailed annual Operational Plans that include the setting and monitoring of key performance indicators, reflective of the Output and Result indicators required under Priority 1.1 of the INTERREG VA call. Board Members have been drawn largely from industry and are at senior levels within their respective organisations. The Board also includes representation from each member of the project consortium. It is envisaged that throughout the implementation of the project that the Board will have a 2:1 majority (or greater) of industry vs. academic members. The project partners consider that the Board has brought a strong track record of industry knowledge to the Centre that has provided the necessary challenge to help guarantee the relevance and route to commercialisation of the PhD research projects. The Board is Chaired by an Independent Chairperson who has been selected on the basis of their international reputation and standing.
Centre Staffing	The Bryden Board has been responsible for the recruitment of the Centre's Management Team and staff complement. The Centre team has been selected on the basis of their research, project management, marine renewable energy and bio-energy expertise – commensurate with their job descriptions. The Management Team is responsible for the day-to-day operations of Bryden including all technical, financial and reporting issues. The Management Team reports to the Bryden Board. **The Bryden Director** is supported by two topic-specific managers:

	i. **A Marine Renewable Energy Manager**; and ii. **A Bio-Energy Manager**. These individuals manage the technical elements of Bryden main clusters and provide support to the Project Managers based within QUB, UHI and LyIT. The Marine Energy Manager and Bio-Energy Manager are responsible for relationship management with project industry participants (and potential participants).

Six work packages have been developed, as follows:

Table 5.3: Summary of Bryden Project Work Plans (per Progress Reports)	
1	Management
2	Work Package WP4 PhD Projects
3	Work Package WP 3 Feasibility Studies
4	Work Package WP5 Project Support Mechanisms
5	Work Package WP 6 Transition
6	Work Package Communication

5.3 Project Budget

The Bryden project received a Letter of Offer (dated 17th July 2017) offering a grant of up to a maximum of €9,367,401.45 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €9,752,679.76, as summarised in the tables below:

Table 5.4: Anticipated Project Costs	
Summary Budget	**Total Project Costs (€)**
Staff Costs	2,596,726.35
Office and Administration Costs	1,869,518.20
External Expertise and Services	4,817,202.84
Travel and Accommodation Costs	121,220.37
Equipment Costs	348,012.00
Total	**9,752,679.76**

Table 5.5: Anticipated Project Funding	
Funding Sources	**Total Value (€) (Public)**
Cash Contribution (Partner Supplied/other grant)	385,278.31
Government Match Funding	1,077,623.69
ERDF	8,289,777.76
Total Grant Funding	**9,367,401.45**
Total Project Costs	**9,752,679.76**
Intervention rate (% ERDF)	85%

5.4 Anticipated Project Objectives, Outputs and Results

5.4.1 Objectives

The Bryden project's Letter of Offer identifies the project's objectives as being to achieve the following:

- A platform to enable cross-jurisdictional academic and industry collaboration.
- Significantly increase the level of business and industry relevant research and innovation in the marine renewable energy and bio-derived energy sectors in the region in order to enhance industry competitiveness in a global marketplace.
- Bridge the gap between scientific and commercial innovation at TRLs 2-6, providing a pathway to commercialisation.
- Provide a critical mass of researchers and pool cross-disciplinary industrial and academic knowledge and complementary capabilities and facilitate knowledge exchange across jurisdictional boundaries.
- Create new knowledge to foster competences in the deployment and development of renewable energy technologies.

5.4.2 *Outputs*

Per the Letter of Offer (dated 17th July 2017), the anticipated (approved) Bryden Centre project outputs are as follows:

Table 5.6: Proposed Project Output Target

Output Indicator	Description	Programme Target	Project Target	Bryden's notes
CO01	No. of enterprises receiving support	20	30	Enterprise partners are to be recruited onto the programme by an Open Call for research proposals.
CO02	No. of enterprises receiving grants	10	8	Company-led research projects will be chosen through an application process. 8 PhD students will transition into 8 companies after completion of their PhD. Bryden will provide 3 months of incentive scheme support towards those individuals' salaries
CO04	No. of enterprises receiving non-financial support	20	30	The recruited companies will receive non-financial support through involvement in the PhD studentship programme.
CO24	No. of new researchers in supported entities	514	132.5	Total of 132.5 full-time researcher years – (127.5 x T1.1.1, 3 x T2.1.1 and 2 x T4.2.1).
CO26	No. of enterprises cooperating with research institutions	10	30	The recruited companies will cooperate with research institutions through The Bryden Centre project.
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	30	The recruited companies will be involved with a cross-border, transnational or interregional element.
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	5	• Queen's University Belfast • Letterkenny Institute of Technology • University of Highlands and Islands • University of Ulster • Agri-Food and Biosciences Institute

5.4.3 Results

Using a Doctoral Training Centre model (as recognised as best practice by RCUK and Horizon 2020), the Bryden project is aiming to directly contribute to the Objective 1.1 result indicator through the development of 68 peer-reviewed journal and conference publications focused upon the Renewable Energy sector. It is anticipated that each of the publications will have cross border authorship and through renewable sector relevance, each will aim to expedite the development of new technologies and the introduction of new products and processes, giving them the potential to create economic impact.

Table 5.7: Anticipated Project Results

Result Indicator	Programme Target	Project Target	% Contribution
The annual number of peer-reviewed journal and conference publications in two sectors (Health and Life Sciences and Renewable Energy) with cross border authorship and with the potential to create economic impact.	75	68	91%

It is anticipated that the project will recruit 34 PhD students (and 5 Post-Doctoral Research Associates-PDRAs). Each student will produce an average of 2 peer-reviewed journal and conference publications as a result of the research work undertaken through their studentship.

5.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the Bryden Centre's key achievements (as of February 2019) and the extent to which the Bryden Centre has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

5.5.1 Key Achievements (to February 2019[54])

At May 2019, due to difficulties in recruiting management staff, the project partners have submitted a modification request to SEUPB for the recruitment of a Centre Manager and suggestions for project underspend to be utilised to include extra PDRA time which the partners suggest will enable them to meet the project objectives and output. The partners, however, note that they require this to be decided upon imminently in order to improve the overall ability of the Bryden Centre to best fulfil its initial ambitions. They note that any continuing delay in the decision significantly limits what can be achieved, increases financial issues and considerably shortens the timelines available to deliver key aspects of the project.

The project partners further note (at May 2019) that whilst a number of potential feasibility studies are in the pipeline following on both from existing collaborators and from contacts made at conferences and meetings attended in the reporting period, there is some sensitivity relating to the sharing of commercially sensitive data which has made some of these difficult to convert to feasibility studies. Albeit, the project partners note that some early enquiries and feasibility study prospects are converting to major scale projects and may seed additional feasibility studies in the future.

The second Bryden Centre summer school was hosted by the University of the Highlands and Islands in June 2019. This well-received event was co-located at Inverness and Oban for the first and second halves respectively. All Bryden Centre students attended and several additional PhD students participated, making a total of 33 students plus 3 Bryden Centre PDRAs, 6 staff and 16 contributors. A

[54] Please note that the key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing.

number of visits were arranged to illustrate both the use of renewable energy technologies in different contexts and to give students a real appreciation of surveying and sea-based investigations. A wide range of topics was covered including Government and regional energy policy, environmental factors, renewable energy, economic development, social science, and professional skills development. Overall, there was a focus on marine energy with students discovering the Scottish regional context including environmental, societal as well as economic and practical considerations.

Figure 5.5: Bryden Centre summer school attendees

- At November 2018, 26 PhD projects were underway, as follows:
  - LyIT had 3 students (with their PhD affiliated to QUB);
  - QUB had 10 students (with 2 more starting in December 2018).
  - UHI had 10 students (with 1 more starting in December 2018);
  - UU had 1 student; and
  - AFBI had 2 students.

- However, on an overall basis, the Bryden Centre was behind on the studentships, with 1 missing at QUB and 4 missing at LyIT. A modification request was anticipated to be made based on those missing studentships.
- The absence of a full-time management team has meant that there has been a delay in the completion of the Bryden Centre Research Strategy. It is anticipated that this will be undertaken when a full-time Centre Director and Post-Doctoral Researchers are in post.
- The focus of the work activity for WP3 Feasibility Studies has been on the recruitment of the Post-Doctoral Researchers who will ultimately carry out the work on the Feasibility studies. However, delays in this recruitment (with only one PDRA appointed at November 2018) has impacted upon the ability of the centre to prepare the feasibility studies.
- The project partners note that engagement with enterprises (particularly industry) has however been good and the Scientific and Commercial Advisory Panel and Interim Centre Director are working together to ensure that the research aims of Bryden are aligned from an academic and industry perspective. This will ultimately inform where the feasibility study work will be focused when the Post-Doctoral Researchers have been in place for a few months
- The first summer school was held in QUB in September 2018, with a Micro-MBA course of 3 days, followed by a day visiting AgriAD plant, and QUB's Marine Lab in Portaferry, and finished with a Student Council meeting.
- A draft Career Development Plan was issued to the students during Period 5 (Staff and Student Symposium). It is anticipated that this will enable students to create a path for their career plan, and report back to the Centre with their updated training.
- At November 2018, no work had been undertaken on WP6 Transition as no suitable candidates (post PhD) were available to be matched with industrial partners.
- Unfortunately, the slow start of the PhD projects has meant that no IP has been identified or generated to date.

The Bryden Centre project partners also cite the project's key achievements (as of February 2019) as being:

Table 5.8: Key Achievements		
Period	**Dates**	**Key Achievements**
1	1st June 2017 – 31st August 2017	• The first three months of the Bryden Centre project involved several key actions focussed on ensuring that the PhD projects for the first cohort, were able to commence on schedule. The following steps were taken: - Appointment of the Scientific and Commercial Advisory Panel; - Appointment of the Board; - Issuance of a call for prospective students; - Hosting of a sandpit event with industry attendance on the 14th and 15th of August; - Issuance of a call for project concepts; - Assessment of the projects by the SCAP and Board; and - Creation of the project website and registration of social media. • These actions led to the generation of 24 project concepts that were endorsed by the SCAP. This exceeded the 19 planned for the first intake of students, allowing the Board to be selective in allocating funding to projects. • Recruitment of Centre Management staff was delayed following delays in agreeing to the Letter of Offer.
2	1st September 2017 – 30th November 2017	• Period 2 saw greater mobilisation of the Bryden Centre with the recruitment of some key personnel (albeit the Bryden Director job description had not yet been agreed by QUB). A number of projects were approved and PhD students began at some of the partner sites. • Project Approval – The 'Standard Project' application form was developed. 34 applications were received, with 19 Projects approved for Cohort 1. • PhD students - 100+ applications were received for PhD studentships. • Wider Engagement / Dissemination included - one to one meetings with businesses, LyIT Energy Awareness Day, EWTEC Cork, ADBA Conference Belfast.
3	1st December 2017 – 28th February 2018	• Launch - The Bryden Centre launch event was held at the Clayton Hotel in Belfast on 17th January 2018. The launch was attended by 81 people from academia, government and industry, all key stakeholders in the sustainable energy sector. The launch involved all project partners, with Irish Minister Joe McHugh the keynote speaker. • Brokerage event - Cohort 2 project development work was undertaken during this period. • PhD students - QUB supported five new researchers in period 3.
4	1st March 2018 – 31st May 2018	• The Bryden Centre Director post was not yet filled and was being resourced on an interim basis. • PhD students – Both QUB and UHI supported two new researchers in period 4. • An open call for projects for Cohort 2 resulted in 47 project ideas being generated from the Inverness Brokerage event on 11th and 12th April 2018. • Subsequently, 26 Cohort 2 project proposals were approved, and posts were advertised through the Bryden Centre website, as well as UHI's and UU's websites.
5	1st June 2018 – 31st August 2018	• PhD students - Cohort 2 studentships were advertised for all institutions.
6	1st September 2018 – 30th November 2018	• Recruitment - QUB recruited their PDRA with a start date of January 2019. LyIT recruited two PDRAs to start in early 2019. • PhD students - QUB recruited 3 PhD students (with a further 2 anticipated to start during December 2018). LyIT had recruited 2 PhD students to start on October 18. UHI had recruited for all remaining PhD students to start either October 18 or December 18. UU had recruited 1 PhD student to start October 18, and AFBI two students to start October 18. This meant that the project partners were missing 1 student at QUB and 4 at LyIT. It was anticipated that

Table 5.8: Key Achievements		
Period	**Dates**	**Key Achievements**
		a modification request would be sent to SEUPB for review in period 7 concerning those gaps. • The first summer school was held during September 2018 at QUB. This included all Cohort 1 students and some from Cohort 2.
7	1st December 2018 – 28th February 2019	**Management:** • Recruitment was underway for the Centre Manager post; • A dedicated Bryden Centre Office was established in LyIT. **PhD Projects:** • 29 PhD studentships were in place across the consortium, some of which were well underway and links with industry were being exploited. **Feasibility Studies:** • With the recruitment of 3 new PDRAs, the identification and exploration of feasibility studies were underway with PDRAs meeting with interested parties to develop the proposals into studies. **Project Support Mechanisms:** • The second summer school for 2019 in Inverness and Oban was in the planning stages, with a number of site visits and seminars and workshops on relevant themes. • Secondments for PhD students were in the planning stages. **Communications:** • Attendance and exhibiting at a number of relevant conferences had been identified and plans were in place to ensure that dissemination and networking opportunities were maximized; • Centre activities were presented at workshops in Egypt and Oman by the Academic Director and a number of PDRAs and students attended, exhibited and spoke at events on behalf of the Bryden Centre.
8	1st March 2019 - 31st May 2019 (from partner reports)	• A significant step forward was considered to have occurred with the appointment of both the Bryden Centre operations manager and the administrative assistant/media specialist. It was suggested that having these two posts filled would help address any outstanding deliverables and to focus all members of the Bryden Centre on achieving and exceeding the impact and benefits to the interregional area that was promised at the outset of the project. • A lot of project work this quarter focused on the Bryden Centre Summer School at UHI in June 2019 (with it anticipated that 42 Bryden PhDs and Post-docs and students from the Renewable Engine project – another INTERREG VA project will attend), developing industry engagements, conferences to promote Bryden Centre research activity and concluding equipment procurement activity. • All student projects were considered to be progressing well with the first cohort now producing several outputs including papers, presentations and posters. • The Bryden Centre was considered to have had a successful time at the All Energy conference held in Glasgow in May. All-Energy is the UK's leading renewable energy event, showcasing the latest technologies and services for the energy supply chain. The conference had over 300 exhibitors and more than 7,000 delegates. Several Bryden Centre PhD students gave presentations and displayed posters of their research work which generated significant interest amongst visitors to the conference. • The Bryden Centre also exhibited at the show which resulted in many new links being made with companies, academics and social enterprises from the UK and overseas. A number of these new contacts have evolved into prospective new projects or other collaborations, offering new pathways for the research undertaken in the Centre to benefit business and communities. • A number of prospective new partners and beneficiaries of the research and capabilities of the Centre were involved in a discussion on both new feasibility

Table 5.8: Key Achievements		
Period	**Dates**	**Key Achievements**
		studies and potential larger-scale investment in the interregional area. While these discussions were preliminary, the Bryden Project Partners considered ***"the prospects of a future collaboration/inward investment/job creation to be promising".*** • The Bryden Centre had extensive coverage at All-Energy in May 2019, exhibiting in the Main Hall and contributing to the Academic Innovation Zone initiative (a collaboration of seven research projects, exhibiting and presenting their work). There were a series of Bryden Centre conference posters associated with All-Energy.

5.5.2 *Progress towards the Project's Output Indicators*

Table 5.9 provides a high-level summary of the progress that has been made by the Bryden Centre project towards its Output Indicators.

Table 5.9: Progress towards the Output Targets

Output Indicator	Description	Programme Target	Project Target	Achieved (at July 2019)	Variance against target	Level of Achievement (at July 2019)
CO01	No. of enterprises receiving support	20	30	47	+57%	Proceeding according to Work Plan. Achieved and ongoing.
CO02	No. of enterprises receiving grants	10	8	0	-100%	Not Started. It is anticipated that this aspect of the project will be taken forward during the last year of the project.
CO04	No. of enterprises receiving non-financial support	20	30	47	+57%	Proceeding according to Work Plan. Achieved and ongoing.
CO24	No. of new researchers in supported entities	T1.1.1	127.5	32.92	-74%	**Behind schedule due to delays in the recruitment of PhD students and PDRAs**
		T2.1.1	3.0	0.37	-88%	
		T4.2.1	2.0	0.0	-100%	
		514	**132.5**	**33.29**	**-75%**	
CO26	No. of enterprises cooperating with research institutions	10	30	47	+57%	Proceeding according to Work Plan
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	30	47	+57%	Proceeding according to Work Plan
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	5	5	-	Achieved and ongoing.

In summary, the Bryden Centre project is progressing towards its project work plan and is on progress to achieve each of its respective output indictors, albeit the Lead Partner notes that their ultimate achievement will likely require an extension to the timeframes stipulated within its LoO.

5.5.3 Target Groups Reached

Table 5.10 provides an overview of the target groups researched as a result of the Project's activity to date.

Table 5.10: Target Groups Reached

Target Groups	Target Value	Target Groups Reached (at Feb 2019)	Examples include:	Target Groups Reached so far %
Higher education and research	5	23	Renewable Engine (the University of Strathclyde, Sligo Institute of Technology, South West College), SPIRE, ETP, ERA and GEN Comm research programmes through the Academic Innovation Zone initiative. Also, Dundalk Institute of Technology and the potential for collaboration around tidal energy, focusing on hydrodynamic performance predictions and acoustic modelling.	460%
Enterprise, excluding SME	5	25	Encirc NI, Horiba Mira, Johnston Matthey, Siemens GAMESA, Trelleborg, Rolls-Royce, Host-Bioenergy, Findhorn Foundation, Scottish and Southern Electricity Networks, The Crown Estate Scotland, Cromarty Lighthouse station	500%
SME	25	43	AgriAD, G-100-EPOWER, Premier Green Energy, Sonas Energy, Solar Marine Energy, Nova Innovations, Global Marine; GlenWyvis Distillery; AWS Ocean Energy; Laminaria; Sustainable Marine Energy; Sonas Energy;	172%
Business Support Organisations	2	29	Marine Scotland Science, Wave Energy Scotland	1450%

5.5.4 *Progress towards the Project's Result Indicator Targets*

Per Table 5.11, it is anticipated that the Bryden Centre Project would contribute 68 peer-reviewed journal and conference publications with cross-border authorship.

Table 5.11: Progress towards the Results Indicator			
Result Indicator	**Programme Target**	**Bryden Centre Project Target**	**Progress as of July 2019**
No. of peer-reviewed journal and conference publications with cross border authorship	75	68	0

As at July 2019, no peer-reviewed journal and conference publications with cross border authorship have been produced. However, the project partners note that a number are currently being progressed and anticipate that this element of the project's activity will ramp up as the research progresses. The project partners also note that they have developed 3 single jurisdiction publications to date.

5.5.5 *Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives*

The Project Partners advise that the project has encountered a number of issues in the delivery of the Bryden Centre project to date. Whilst noting that some of these issues have combined to slow progress towards elements of the output indicators (e.g. the number of PhD years), the Project Partners do not anticipate that these will ultimately have an adverse impact on the longer-term achievement of the Project's Output and Result indicators and the Priority's Specific Objectives.

Specific issues identified by the Project Partners include:

- **Delays in the appointment and retention of the project's core staff** – It was initially anticipated that the project would appoint a project Centre Director (who would spend 80% of their time on the project). However, due to competing academic demands, the member of staff who initially commenced this role was required to divert their attention to an alternative pre-existing role. The role was subsequently split into an Academic Director (whose role is more overtly focused on the research aspects of the project) and an Operational Manager (whose role is more overtly focused on the operational and commercialisation aspects of the project).

  In addition, the Project Partners note that there have been a number of changes to aspects of the project's core administrative staff. For example, the finance and administrative assistant role has had to be refilled on two occasions;

- **Delays in the recruitment of PhD students and wider research staff** to support project delivery - Consultation with the Project's Partners indicate that there were delays in the recruitment of PhD students[55] and wider research staff to support the delivery of the project. The Project's Partners are of the view that this situation may have arisen due to the fact that a number of different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the Renewable Energy sector. This inadvertently created significant demand within the market for these students at the same time, resulting in a shortage of available students and, by association, delays in recruitment;

- **Student mobility issues** – Whilst not deemed to be a significant issue, the Project Partners note that they have faced some minor difficulties in non-EU resident PhD students travelling outside their country of research residence;

- **EU and SEUPB Procurement requirements hindering the progression of research** - According to one of the project's partners, the progression of research has been hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed

[55] As noted, the Project Partners have recruited 32 of the 34 PhD students and anticipate that the remaining two will be converted to PDRAs.

to conduct research. It was noted by this project partner that the additional 'checks and balances' required by SEUPB provide a significant additional administrative burden over and above the existing EU requirements; and

- **Geographical logistics are hindering the development of a 'centre' ethos and the development of PhD students** – Whilst noting the anticipated benefits from adopting a transnational and cross-border approach to programme delivery, the lead Project Partner notes that this requirement has inadvertently created logistical difficulties in terms of bringing research staff together and promoting a wider 'Centre' ethos.

5.6 Best Practice and Learning

The Bryden Centre project partners report that the project has resulted or will result in the following areas of best practice and learning:

- **Development of PhD's industry and commercial focus through the delivery of project secondments -** Whilst yet to be implemented, the Project Partners note that the project's PhD students will undertake a secondment with an industry partner in the final year of the project. It is anticipated that these secondments will support the development of the students' commercial acumen and understanding of industry's needs, develop practical skills (e.g. communication and time management), as well as potentially enable the students to see the practical use of the research findings that they have been working on during the research phase; and

- **Enhanced project progress and PhD student development through the use of multiple Project supervisors across the eligible region -** In addition to receiving ongoing project support from their own academic institution, each PhD student is allocated a supervisor in another area within the eligible region. It is the project partners' view that this aspect of the project supports the cross-pollination of skills and knowledge to both expedite the progress of projects and address project-specific issues that arise, as well as contribute to the wider development of the PhD students.

5.7 Synergies between Projects funded

Given their focus on the renewable energy sector, the Project's Partners note that they have undertaken a number of meetings with the Project Managers of the Renewable Engine and SPIRE 2 projects to discuss project progress, share knowledge to address project-specific issues and identify further opportunities for collaboration.

According to the project partners, by working with the manufacturing sector in the development of renewable energy products, the partners will be developing manufacturing capacity which may be needed for the delivery of projects such as SPIRE and the Renewable Engine. For example, given the focus of both projects to undertake research in the area of anaerobic digestion, the Renewable Engine's and Bryden Centre's project managers are in the process of identifying potential project synergies and opportunities to collaborate.

It is further noted that a number of PhD students from the Renewable Engine project attended the Bryden Centre Summer School at UHI during 2019 which served to (inter alia) enhance the levels of industry engagements, provide an overview of the project's research and capabilities. Finally, it is understood the discussions are ongoing with the SPIRE 2 project to identify opportunities for joint PhD training.

Additionally, the Bryden Centre, Renewable Engine and SPIRE 2 are working closely together with the Advanced Forming Research Centre (AFRC) at University of Strathclyde, Energy Technology Partnership (Scotland) and CASE (NI) in delivering regular joint showcasing and presentations of the PhD work in renewables and energy storage at events such as All-Energy Conference and Exhibition in Glasgow. The event in 2019 was deemed by the Project Partners to have been a major success with several Bryden Centre presentations being made in collaboration with both Renewable Engine and SPIRE 2. Preparations are underway for the Innovation Zone showcase at All-Energy in 2020.

5.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the Bryden project's collaborative and partnership working including:

- The effectiveness and added value of the Bryden project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

As noted previously, whilst a variety of discussions and indeed some activity had been taken forward (prior to the application for INTERREG funding being made) on a collaborative basis between the project partners on a cross-border, interregional basis, it is understood that this has been, small scale and piecemeal (as a result of jurisdiction-driven funding restrictions and market failure). However, following early indications that INTERREG VA would comprise an R&D element with a focus on renewables, the five research institutions and industry specialising in marine and bio-energy commenced a series of cross-border and interregional workshops, which sought to identify:

- Opportunities to renew relationships and build new ones, and to encourage increased cross-border communication, networking and cooperation;
- Challenges that are shared across the jurisdictions, and to build awareness of the interconnectedness and interdependence of the renewables ecosystem on both sides of the border, and with Western Scotland;
- Opportunities for wider industrial engagement and cooperation;
- Potential solutions to address common issues and concerns;
- Opportunities to encourage the sharing and learning of good practice through the establishment of joint projects and activities;
- Projects that would deliver impacts that are improved and additional to those that would otherwise (if at all) be achieved by a single jurisdictional approach.
- Opportunities to create a sustainable and strategic cross-border industry/academia forum that can:

    - Strengthen institutional and organisational capacity to undertake renewable energy-related R&D activity;
    - Proactively influence the development of policies and structures which support the development of the renewable industry, but that more appropriately managed on a cross-border, interregional basis.

The outworking's of these workshops was the Bryden project proposal which had been agreed by industry stakeholders and the project partners on a cross border basis, as representing a key mechanism through which the issues identified might be addressed.

The Partners consider that extensive technical know-how and market activity is available within the eligible region relating to marine and bio-energy, but that it is fragmented at both academic and industry level. Bryden is, therefore, serving to facilitate cooperation and partnership based on mutual exchange of knowledge and experiences that are anticipated to lead to a final result that differs qualitatively from the sum of the pre-existing activities undertaken at the level of the three jurisdictions.

The project partners note that Bryden has provided the setting for interaction that would not occur in its absence, cooperation that goes beyond local, regional or even national interests and is facilitating the development of synergies at the level of the cross-border/interregional territory and the achievement of a series of shared objectives. Furthermore, the project partners are hopeful that it will also provide the foundation for even more ambitious R&D projects funded through mechanisms such as Horizon 2020.

In addition, the project partners note that the Bryden Centre is supporting activity that will:

- Encourage industry to explore collaborative research projects that are of economic significance and of supra-national policy concern, at a lower TRL than has previously been the case;
- Encourage industry to explore cross-border and cross-jurisdictional collaborative research projects that would not be feasible otherwise;
- Encourage Research Institutes to share and combine complementary skills and knowledge on a cross-border, cross-jurisdictional basis that would not occur otherwise, and thus increase the overall quality of research being undertaken within the eligible region.

According to the project partners, the scope of the management of the project and the implementation of the individual research projects is ensuring that activities are coordinated and carried out across the full partnership ensuring involvement by all partners on a cross border basis. Joint implementation is taking place at a variety of levels, as follows:

- Efficient joint development, management and operations (financing, staffing etc.);
- Decision making and commitment through the Scientific and Commercial Advisory Panel and the Board;
- Research project-level cooperation at both an industry sector level and cluster level;
- Exchanges of information and experience amongst industry, academics and PhDs. Of note, all PhD projects will be co-supervised on a cross-border basis;
- Networks and clusters that will be formed;
- Single data monitoring and recording systems.

The project partners consider that the added value of the project partners working together on a cross-border basis will include:

Economic Impacts	• Increased engagement of SMEs in R&D activity, and associated expenditures; • Enhanced economic growth and employment; • Great levels of competition, trade and investment, including on a cross-border basis; • Improved productivity and resource efficiency; • Lower cost of marine renewables; • Reduction in barriers for suppliers and service providers; • The introduction and dissemination of new production methods, technologies and products.
Environmental Impacts	Positive impacts on: • Production, uptake and usage of renewable energy; • Climate, air and water quality through the reduction in the emission of greenhouse gases or ozone-depleting substances or other harmful pollutants into the atmosphere; • Biodiversity, flora, fauna; • Land use; • Waste production, generation and recycling.
Social Impacts	• Enhanced understanding of social attitudes and behaviours that might hinder or facilitate the progress of the renewables industry within the eligible region; • Enhanced capacity of individuals to participate in economic life. • Improved environment, leading to health and wellbeing benefits.
Cooperation Impacts	Impacts that are anticipated to arise specifically from the process of cooperation as proposed by Bryden include: • Project-level cooperation • Exchanges of information and experience (formal and informal) • Networks (formal and informal) • Joint development and management • Integrated management • Joint operations (development, financing, implementation, staffing) • Fully-integrated transnational programme management systems • Single data monitoring and recording systems A potential outworking of some of the research projects may be to act as a key influence upon:

	• High-level strategic consultation between Ministers and regional participants; • The cohesion of regional policy; • The creation or harmonisation of regulations, legislation and/or shared enforcement within the cross-border territory relating to marine and/or bio-energy, through the systematic use of project results and the formulation of joint recommendations; • The creation of new protocols or voluntary agreements for the management and delivery of public services; • New management processes and procedures (e.g. meetings, structuring and coordinating networks of the industry and academic bodies involved).

5.9 Impact on Business and Industry

This section considers the impact of the Bryden Centre project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

Notwithstanding this, anecdotal feedback from the Project Partners suggests that the project has served to (at least in part):

- Stimulate significant additional investment by a project industry partner (Agri AD);
- Develop the skills and knowledge of PhD students, many of who will ultimately work in industry in the future. It was further noted that the planned project secondments will facilitate the transfer of knowledge between academia and industry;
- Increase businesses' knowledge and understanding of the benefits of working collaboratively with academic institutions which may result in the development of longer-term working relationships;
- Linked to the previous point, the Project Partners note that businesses have developed a greater understanding of the respective research strengths and capabilities that exists within the academic institutions; and
- Increase academia's understanding of the needs of industry.

The lead Project Partner also noted that the INTERREG VA Programme's requirement for support to be channelled to fund PhD studentships may inadvertently hinder longer-term economic development in the eligible region as a number of the PhD students that have been recruited have been outside the eligible region and may return to their country of residence resulting in a loss of knowledge and skillsets.

5.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the Bryden Centre project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

5.10.1 EU2020 Objectives

The Bryden Centre project continues to offer the potential to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth. Furthermore, the Bryden Centre project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

5.10.2 The Atlantic Strategy

The Evaluation Team notes that elements of the Bryden Centre's project's research (e.g. Enhancement of Marine Energy Assets through Validated Numerical Modelling and Optimisation, and the Adoption of Building Information Modelling (BIM) for Lifecycle Management) is overtly focused on developing offshore energy generating technologies and hence offers the potential to contribute to key themes underpinning the Atlantic Strategy including the 'Reducing Europe's Carbon Footprint' theme which advocates that steps should be taken to exploit the Atlantic's powerful waves and strong tides to generate renewable energy.

5.10.3 The Horizontal Principals

The Bryden Centre project partners consider that the project will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

Sustainable development	By focusing on the development of Advanced Marine and Bio-Energy, Bryden seeks to identify methods to allow society to better live within its environmental limits, and thus seek to address the many negative consequences that not doing so creates, such as climate change. However, Bryden's focus is broader than just the environment. It's also about ensuring a strong, healthy and just society within the eligible region. As well as technological focused projects, the Bryden project partners suggest that they will support socio-economic focused projects that will aim to ensure that marine and bio-energy projects meet the diverse needs of all people in existing and future communities, help to promote personal wellbeing, social cohesion and inclusion, and have the potential to create equal opportunity, particularly in isolated rural areas. They suggest, for example, that the marine energy sector is clearly a socio-technical system, which faces major interrelated socio-economic and regulatory challenges, in addition to a need for technical innovation. Non-technical challenges include sufficient levels of market, community and socio-political acceptance of marine energy; aligning regulatory and governance regimes to address issues raised by the expansion of the sector; developing a collaborative supply chain; and realising opportunities for community benefits and ownership. In this context, one of the suggested Bryden research projects (amongst other potential socio-economic focused projects) is to critically examine the circumstances that give rise to key socio-economic challenges relating to the deployment of marine energy, explore their interrelationships and evaluate and share good practice. In conjunction with industry and community partners from across the eligible region, this proposed project aims to establish transferable models of good practice and innovative solutions in relation to four inter-related marine energy deployment challenges: increasing social acceptance; improving regulation and governance; developing collaborative supply chains (particularly utilising local business services and products); and increasing community benefit and ownership (and thus create more sustainable rural communities, encourage social cohesion and inclusion and enhance personal wellbeing). The suggested project would develop tailored strategies to overcome these challenges i.e. provide elements of good practice from which other similar communities may learn. Bryden projects such as the example project outlined above will directly seek to ensure that the development of Advanced Marine and Bio-Energy within the eligible region balance social, economic and environmental aspects. Bryden recognises that much of the region's potential marine and bio-energy activity will likely occur in rural and isolated coastal areas. Bryden will therefore actively explore how the development of these technologies and renewable energy sources can help provide employment (either through self-employment or through investment into the area), prosperity and opportunities through participative systems and structures that will engage both businesses and local communities (perhaps through the development of social enterprises to become supply chain partners), and which may incorporate elements of education, training and the development of new skills amongst rural communities, so as to combat deprivation and disadvantage, including fuel poverty (through the creation and use of marine and bio-energies).

	The potential to contribute to sustainable development (and how it will be monitored) is one of the criteria that has been used to score and select Bryden projects. This has included, for example, consideration of factors such as environmental protection plans, resource efficiency, climate change mitigation impact etc. Environmental Impact Assessments have been conducted on all relevant projects before a project has been supported[56].
Equal opportunities and non-discrimination	Each of the project partners has equal opportunity and non-discrimination policies that adhere to EU legislation and the various legislations of their respective jurisdictions. Bryden has sought to ensure that it robustly promotes equality of opportunity between men and woman and does not discriminate on any grounds, including sex, racial or ethnic origin, religion or belief, disability, age or sexual orientation during its preparation and implementation. The project partners consider that there has been no differential impact on any of the groups listed. A programme specific equal opportunities policy has been developed to ensure that each project partner complies with its equality obligations under anti-discrimination law. This benefits both Bryden staff and PhD students. QUB and the Centre Director are responsible for ensuring that all aspects of the policy are complied with, addressing any complaints that might arise, and for monitoring and reviewing its implementation. The Project Partners have taken steps to fulfil their commitments set out in the policy by: • Communicating the policy to employees, PhD applicants and relevant others (e.g. business participants); • Incorporating specific and appropriate duties in respect of implementing the policy into job descriptions and work objectives of all programme staff; • Providing equality training and guidance as appropriate, including training on induction and management courses; • Ensuring that those who are involved in assessing candidates for recruitment or promotion have been trained in non-discriminatory selection techniques; • Incorporating equal opportunities notices into general communications practices (e.g. staff newsletters); • Obtaining commitments from other persons or organisations such as participant businesses that they too will comply with the policy in their dealings with the programme staff and PhD students; • Ensuring that adequate resources are made available to fulfil the objectives of the policy.
Equality between men and women	Bryden has sought to ensure that it robustly promotes equality of opportunity between genders. The Project Partners have ensured that both women and men have equal rights, responsibilities and opportunities in all areas of the Centre's activities. They are afforded equal opportunities for occupational achievement and advancement. In order to promote equality, the Project Partners have, with due regard to the available resources and other relevant factors: • Acted so that both women and men apply for vacancies. Centre publicity has ensured to convey that it is an equal opportunities employer; • Promoted equitable recruitment of women and men in the various jobs and PhD positions, and created for them equal opportunities for promotion and advancement at work. Recruitment and selection procedures are suggested to have been fair and founded on the principle of objectively selecting the best person for the job;

[56] NB Working at TRL levels of between 2 and 6 typically means that it is unlikely that Bryden will involve projects that require an in-depth Environmental Impact Assessment as required under jurisdictional legislation, as these will normally apply to larger scale, latter TRL, prototype development and testing. Nevertheless, due diligence is applied to the legislative processes within the jurisdictions. Where some small-scale testing is required e.g. in the marine renewable energy sector, then exemptions from the EIA and licencing regulations are usually applied by the regulatory authority under scientific and research provisions.

	• Developed working conditions suitable for both men and women, and facilitated the reconciliation of working life and family life for women and men; • The Centre has introduced an anti-harassment and bullying policy. • Complaints of discrimination and harassment will be dealt with promptly and seriously. All employees, but especially those with supervisory responsibility and those who made/will make recruitment and selection decisions, are familiar with equal opportunities principles and with Bryden's policies and procedures. The project partners have stated that the policy will be monitored by collecting data about the profile of the workforce, applicants and appointees in terms of characteristics such as community background, sex and disability and, reviewed and analysed periodically. Positive or affirmative action will be taken, where appropriate e.g. where the analysis of monitoring data reveals that certain groups are under-represented in the workforce/PhD intake or are experiencing disadvantage compared to other groups.

5.10.4 *Contribution to Other Strategies*

On a national and regional basis, the table below summarises a number of key strategic targets which Bryden has the potential to contribute towards achieving:

Table 5.12: Bryden Project Contribution to Other Strategies

	Strategy	Targets which the Bryden has the potential to contribute towards:
UK	Renewable Energy Action Plan and Roadmap	• 15% of energy to be sourced from renewable resources by 2020 (including 1,300MW from ocean energy and 38,210 from bio-energy) by 2020
	UK Bioenergy Strategy	• Sustainably-sourced bioenergy to contribute c.8-11% to the UK's total primary energy demand by 2020 and c.12% by 2050
NI	Strategic Energy Framework 2010	• Harnessing the abundant renewable resources to enable 40% of NI's electricity consumption to be generated from renewable sources by 2020. NIE Networks and SONI recently reported that this would equate to c. 1,600 MW of renewable energy
	Offshore Renewable Energy Strategic Action Plan 2012 – 2020	• To optimise the amount of renewable electricity sustainably generated from offshore wind and marine renewable resources in NI's waters
	Bioenergy Action Plan for Northern Ireland 2015-2020	• To continue to encourage focussed and NI relevant research into bioenergy and further work to address gaps in knowledge and identify future research actions.
	NI Framework for Smart Specialisation	• More young people graduating with graduate and postgraduate qualifications in STEM disciplines (baseline of 42%); • Employment in the NI knowledge economy increasing from 32,000 to at least 52,000.
Ireland	Irish Renewable Energy Roadmap	• 16% of energy to be sourced from renewable resources (including 75MW from ocean energy and 5,111MW from bioenergy) by 2020.
	Harnessing Our Ocean Wealth	• Double the value of ocean wealth to 2.4% of GDP by 2030. • Increase the turnover from the ocean economy to exceed €6.4bn by 2020.
	Donegal County Development Plan 2012-2018	• To facilitate the development of Donegal as a Centre of Excellence for Renewable Energy
	DCENR Draft Bioenergy Plan (2014)	• Over 3,500 kilotonnes of oil equivalent of indigenous resources being available for the bioenergy supply chain by 2050 • Creation of up to 8,000 net new jobs, mostly in rural locations
	Ireland's Smart Specialisation Strategy	• Marine renewable energy to present one of 14 priority areas for publicly-performed research
Scotland	2020 Route-Map for Renewable Energy in Scotland	• 100% electricity demand equivalent from renewables by 2020 • An interim target of 50% electricity demand equivalent from renewables by 2015 • 11% heat demand from renewables by 2020 • At least 30% overall energy demand from renewables by 2020
	Dumfries and Galloway Renewable Energy Action Plan	• 10% Increase in GVA generated by the renewable sector and 1,000 jobs created or safeguarded in the sector by 2020

Given the stage of research being undertaken (i.e. between TRLs 2 and 6), it is not possible at this stage to quantify the extent of the specific contribution towards renewables targets which will be made by the

Bryden project. However, it is understood that the industry-led research projects will seek to find solutions to barriers to growth to enable the eligible region to fully capitalise upon its natural resources in order to generate economic returns (including increased GVA and skilled employment) and environmental benefits.

In summary, the Evaluation Team is of the view that the Bryden Centre project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

5.11 Barriers to Cross-Border Cooperation

This section considers whether the Bryden project has encountered any barriers to cross-border cooperation that the priority axis is not addressing.

Specific issues identified include:

- State aid rules relating to the provision of financial support to businesses have, in the Project Partners view, limited potential levels of engagement with industry; and
- The need for additional knowledge transfer support to aid commercialisation. For example, it was suggested that it would be beneficial for a Technology Transfer Officer to be appointed to bridge the gap between academia and industry.

5.12 Exit Strategy

The project partners anticipate that during the life of the INTERREG VA funding period, Bryden will demonstrate the considerable added-value that can be achieved through strong and relevant partnerships between research institutions, relevant agencies and private sector on a cross border basis.

Whilst the Bryden project partners envisage that some functions may be subsumed into their core activities, they are aiming to attract further funding to continue activities beyond the lifetime of the project. Key channels that are anticipated to be explored in order to extend the project outcomes achieved through the INTERREG VA funding include:

- The governments of the three jurisdictions; and in particular
- EU funding through funding streams similar to Horizon 2020 that support cross-border, interregional R&D projects.
- National and international funding streams including research councils, Innovate etc.
- Development of a pipeline of internationally marketable research and training courses.

At opportune junctures throughout the delivery period, the partners intend, where appropriate, apply for other sources of funding to ensure the sustainability of the Centre.

It should also be noted that it is anticipated that some of the research projects will result in the creation of Intellectual Property. The project partners envisage that any revenues derived from such IP will be utilised to ensure the sustainability of the Centre.

6. SPIRE 2 - STORAGE PLATFORM FOR INTEGRATION OF RENEWABLE ENERGY

6.1 Introduction

This section of the report considers the SPIRE 2 project, which was awarded grant funding under Priority Axis 1 – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry relevant research and innovation capacity across the region.

6.2 Project Overview

6.2.1 Background

The eligible area is considered to possess some of the best variable renewable energy (wind, wave and tidal) resources in Europe[57]. For example, Scotland possesses 25% of EU offshore wind resources and almost all UK marine energy resources. Northern Ireland and Ireland have some of the best wind resources in Europe[58], and the Marine Institute of Ireland state that wave energy resources potentially available to Ireland could meet 75% of Ireland's electricity requirement[59].

The exploitation of these resources is integral to meeting energy-related emissions targets and contributing to energy security. Indeed, challenging energy and environmental targets of reducing CO2 emissions from the combustion of fossil fuels have led to wind energy becoming the dominant variable renewable energy (VRE) source in the eligible area. The island of Ireland has 240 Wind Farms and 3083MW installed wind energy capacity[60], equivalent to over a quarter of the all-Ireland electricity supply capacity. Renewables are the single largest contributor to electricity generation in Scotland. In 2014, the largest renewable technology generator was wind with 62%[61].

However, the UK's Institute of Mechanical Engineers states that the intermittency challenge of renewable sources arises from the fact that the wind does not always blow, the sun does not always shine and the waves and tides are not always in motion at times when consumers demand electricity. On the other hand, the converse is also true, in that consumer demand for power can be low when renewable energy sources are highly active[62].

Because VRE resources cannot be controlled, integrating them into power systems which have grown around controllable fossil fuel generators requires a range of measures to guarantee reliable electricity supply. These measures include varying the output of controllable generators, turning down/off output from VRE sources, interconnection (power flows to/from neighbouring electricity networks), demand-side management (increasing/decreasing consumer demand to match supply) and, central to the SPIRE 2 project, energy storage (storing excess energy for later use). Energy can be stored either in bulk using large, grid-scale devices, or at the distributed level, using smaller devices owned and operated by domestic and business consumers. While there has been considerable progress in grid-scale schemes (for example, the underground compressed air storage system examined in the SPIRE 1 Project), there has so far been limited development of distributed energy storage.

This issue of 'wrong time' electricity generation leads to technical challenges in balancing supply and demand across the power transmission and distribution system. Currently, in such cases, the renewable generators are often simply switched off. Under previous market arrangements, an energy company unable to supply its electricity output to the grid is entitled to 'constraint payments'. However, this subsidy has since been removed for onshore wind[63]. When such a subsidy was in place, National Grid constraint payments to wind farm operators were about £34 million between 2011 and 2012. Thus, the

[57] UK Renewable Energy Roadmap. July 2011, Department of Energy and Climate Change, URN 11D/698
[58] https://www.economy-ni.gov.uk/articles/wind-map-northern-ireland
[59] http://www.marine.ie/Home/site-area/infrastructure-facilities/ocean-energy/marine-renewable-energy-resource
[60] http://www.iwea.com/windstatistics
[61] http://www.gov.scot/Topics/Business-Industry/Energy/Facts
[62] Energy Storage: The Missing Link in the UK's Energy Commitments. Institution of Mechanical Engineers, 2014.
[63] https://www.gov.uk/government/speeches/statement-on-ending-subsidies-for-onshore-wind

curtailment remains with a significant drop in income for wind farms, meaning energy storage must become an option.

Energy storage provides a potential solution in that it would enable wrong-time electricity generated from intermittent VRE sources to be put to use at times when consumer demand is higher than baseload provision and renewables supply is at low levels.

The project partners also note that renewable energy system performance degradation over time is important for wind energy, the most common large scale VRE resource. The performance degradation is significant in harsh offshore environments and maintenance is challenging. Therefore, the performance loss is accepted and therefore it should be accounted for in energy storage sizing.

The commitments to renewable energy by the governments of the eligible area are seen in potentially new targets of 75% Renewable Electricity (Ireland via DS3)[64] and Northern Ireland (potentially greater under the UK Government acceptance of the Committee on Climate Change's 5th carbon budget recommendation of 57% Reduction in CO2 levels when compared to 1990 by 2032)[65]. This will see the deployment of new energy technologies requiring variability management i.e. energy storage.

The Scottish Government, DECC and others suggest that if market barriers to energy storage are removed, energy storage systems could unlock £2.4bn of annual savings across the UK by 2030, saving households £50/year on their energy bills[66]. In addition, Ricardo-AEA reported to the NI Department of Economy that energy storage was necessary to support high levels of Northern Ireland renewables so that NI can gain maximum benefit[67].

SPIRE 2 also draws together the following series of previous and current research:

1. The performance of Variable Renewable Energy (VRE) systems e.g. wind deteriorates with time. Maintenance schedules based on harsh environmental were conditions must be balanced against economic outputs of energy production. Complex arguments are required to draw together impacts of wear, energy production, the loss of UK onshore wind farm subsidies and new electricity market structures to optimise energy storage size and type. Thus, there is a need to translate fundamental wear studies into impacts on real wind (and later marine) energy systems and subsequent electricity market operations which builds upon the RCUK Wind Centre for Doctoral Training. Strathclyde University Doctoral Training Centre in Wind Energy is working closely with industry to help develop its global position in the wind energy field and meet ambitious renewable energy targets. Past projects have focussed on Aerodynamics, control, drivetrains, electrical systems, power networks, maintenance, design, economics and policy and will add the extra dimension of storage characteristics.
2. Electricity markets are changing. Ireland (i-SEM, DS3), Scotland (the UK, Contracts for Difference, Balancing Agreements) and interconnection between these markets will occur as well as ultimately the realisation of the new European Target Market Model within Ireland which i-SEM is a step towards. The UK position is more fluid in a post-BREXIT situation but interconnection and the Northern Ireland/Ireland shared markets will ensure a multifaceted market interaction. Superimposed upon this is the role of VRE resources and their impacts on electricity networks and electricity markets driven by decarbonisation of electricity generation. Therefore, the size and type of distributed energy storage need to work within emerging market structures in order to be successful. Such market model development must both follow its designated pathways but also inform regulators on more beneficial routes and the benefits of distributed energy storage.
3. Energy storage technology development at Ulster include Ulster's finished projects of EU FP7 Einstein (Seasonal Thermal Storage) and EU FP7 Merit (Compact Thermal Storage) which revealed the high cost and unsatisfactory performance of otherwise theoretically excellent approaches. Sunamp has a phase change material system that would benefit from greater compactness (the current model weighs 1000kg)

[64] http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-Programme-Brochure.pdf
[65] https://www.theccc.org.uk/publication/the-fifth-carbon-budget-the-next-step-towards-a-low-carbon-economy/
[66] Cracking the Code: A Guide to Energy Storage Revenue Streams and How to Derisk Them, Everoze, July 2016
[67] https://www.economy-ni.gov.uk/sites/default/files/publications/deti/Review%20of%20the%20Costs%20and%20Benefits%20of%20the%20Northern%20Ireland%20Executive%e2%80%99s%2040%25%20Renewable%20Electricity%20Target%20-%20Final%20Report_1.PDF

and more efficient operation (new materials and new heat exchangers). Current Ulster projects of EPSRC i-STUTE (heat pumps and thermal storage), EPSRC 4S-DHW (advanced heat pumps), H2020 Inpath-TES (thermal energy storage PhD and MSc education) and H2020 Chess-Setup (Seasonal Thermal Storage) are advancing heat pump elements of thermal energy storage and not the thermal storage element. QUB projects include the AES/QUB 10MW Li-battery project for Kilroot Power Station which addresses electricity system constraints and aids in the integration of variable renewable generation, avoiding wind curtailment and optimises electricity generation system dispatch. In contrast to the Ulster energy storage projects, this Innovate UK project is concentrated on the market applications of fast frequency response, fast ramping and operating range, synthetic inertia, reactive power control and black start capability. New markets structures, varying sizes of electrical storage, network constraint management and customised electrical storage technologies for specific tasks (i.e. rates of charge and discharge) are gaps in the knowledge benefitting, for example, Arbarr and AES.

Based upon this, the Project Partners consider the gaps in knowledge to be extensive, noting that:

a) Markets are changing and new market models must accommodate the established benefits of energy storage operating with VRE resources.
b) VRE resources performance degrades over time and the loss of offshore subsidies coupled with offshore weather-related maintenance and ease-of-access challenges generates a complex problem of distributed energy storage sizing within electricity network capacity constraints.
c) Distributed energy storage technologies must be optimised to operate within these new markets and constraints through either the storage of electricity or the electrification of heat in the first instance. New technologies must operate within technical, social and economic constraints defined by scales of end-users ranging from energy utilities to industrial complexes to communities to our homes.

It is envisaged that the SPIRE 2 will draw these complex challenges together into a viable pathway for the deployment of optimised energy storage solutions that benefit not only energy utilities, industrial complexes, communities and homes but also electricity transmission operators and distribution system operators and government's attempts to reach sustainability targets.

Decentralised energy solutions have the potential to transform the UK and EU energy industry from a nationalised model managed through governmental, regulator and utility led structures, to a customer-centred model where local integrated energy solutions are determined at a local level through consumers, business and communities. Photovoltaics (PV) and wind power are proving to be a significant contributor to the electric supply mix in this new customer-centred model. However, there are operational challenges poses by distributed PV and wind – especially in residential areas and in parts of the distribution system with high penetration of such renewable sources.

The continued increase of distributed renewable energy generation poses challenges for the energy system and for Distribution System Operators (DSO), namely:

- Due to the variable intermittent and unpredictable character of renewable energy, such as solar-PV and wind, high fluctuations will occur in the system. This will be especially the case since the time and amount of generation will not often take place simultaneously with demand. The grid is not designed to transport these high peak loads and therefore congestion can occur, for example in the summertime during high peak production of solar-PV. This congestion could ultimately result in a system overload, which in turn triggers grid safety systems to switch off a specific area to prevent damage to the infrastructure, resulting in a power outage in that area.
- The variability of renewable energy requires additional balancing power. If balancing power and inertia from conventional power plants is insufficient or lacking, they will have to be replaced or completed by other solutions.
- Fast deployment of distributed renewable energy generation will most likely exceed the capacity to install additional grid reinforcements in some areas. This is caused by a difference in installation time between grid reinforcements and new renewable generation installations.
- The feed-in of especially solar-PV leads in some cases to power quality issues where the voltage level exceeds the required specifications, which could potentially lead to damaged consumer's equipment.

In addition, DSOs are facing a change in energy consumption patterns, with an increasingly variable and concentrated load on the grid – heat pumps, electric vehicles, air conditioning systems – mostly in peak hours and in high-density urban territories.

DSOs must ensure that the distribution grid is robust enough to guarantee the security and quality of supply yet is agile enough to allow the speedy connection and successful integration of distributed generation. Currently, DSOs tackle these challenges by reinforcing the grid with additional capacity where necessary. The expected growth of renewable energy generation and change in electricity consumption patterns will require a huge investment in grid reinforcements and smartening: the European Commission calculated that up to 2020, distribution grids would require a total investment of €400 billion.

Next, to grid expansions and reinforcements, other options for a DSO to manage congestion and voltage problems are:

- Local flexibility market: when congestion problems are foreseen, a local flexibility market could be developed. Local flexibility is then priced to reflect the scarcity of distribution capacity.
- Curtailment: the generation of energy or the consumption level is limited, based on the available distribution capacity.
- Energy storage: the excess amount of energy is buffered in the grid and released later.

This is where storage has proved to an essential enhancement to decentralised energy markets particularly where they can be economically and effectively integrated into the energy system. There is however a degree of uncertainty how these integrated renewable and storage systems can participate in the energy markets. Europe's existing electricity system and markets with implications for rules and regulation were constructed around a centralised model dominated by large-scale generation and power and these rules do not easily transfer to the smaller participants[68].

The project, therefore, aims to help address the significant variable renewable energy (VRE) resources the region possesses and the challenges their large-scale deployment raises.

6.2.2 SPIRE 1

The SPIRE 1 (Storage Platform for the Integration of Renewable Energy, 2013-2015) was a £2.9m research programme that aimed to establish the likely future value of energy storage as a variability management mechanism for the all-Ireland Single Electricity Market. This was achieved through a scenario and market modelling and aspects of research and demonstration in order to illustrate the storage technologies best suited to meeting market needs at the small (domestic), medium (distributed) and large (utility) scale.

The focus of the SPIRE Project was therefore to minimise the barriers to the deployment of renewable energy by providing viable answers to energy storage challenge.

The SPIRE project was led by Ulster University's Centre for Sustainable Technologies partnered by the Centre for Renewable Energy at Dundalk Institute of Technology and was funded by European Union's Interreg IVA Programme.

The technologies under investigation included heat pumps and thermal storage at a domestic level, flow batteries and ice banks at a commercial/industrial distributed scale and compressed air energy storage at the large utility-scale. Ulster led on modelling, scenario development and demand-side manage options with heat pumps and thermal storage, DkIT led on flow batteries and ice banks, while Gaelectric Energy Storage Ltd. was appointed as the lead contractor to develop practical and theoretical assessments for compressed air energy storage.

[68] CEDEC Position Paper: Storage as a Tool for Smart Distribution. January 2016.

SPIRE 1 resulted in 11 Publications and it co-hosted the 21st ICE/IEEE Conference on Engineering, Technology and Innovation in June 2015 in Belfast with over 170 international delegates. Conference papers were presented by project partners and industrial presentations were delivered by relevant national and international organisations, demonstrating SPIRE's significance. In recognition of such results, the SPIRE 2 project partners note that Compressed Air Energy Storage (CAES) gained PCI status[69] (EU Project of Common Interest, 1.12 Compressed air energy storage in the United Kingdom — Larne, €6.5m) for design studies. Gaelectric is also to receive some €8.28m in funding from the EU to drill an appraisal well, and detailed studies into the design and commercial structure of the project.

In terms of the link between SPIRE 1 and SPIRE 2, the project partners suggest that SPIRE 1 primarily focussed on large scale energy storage e.g. Compressed Air Energy Storage. SPIRE 2 recognises the potential future contribution of large-scale energy storage at Transmission System-level and models potential scales, impacts and also impacts of interconnection to other electricity markets. This indicates future capacity at a large scale and will have some impact at the electricity Distribution Network Operator level. However, it is the changes at DNO level (renewables on buildings, electrification of heat and transport etc. as dictated by UK Net Zero Emissions policy for 2050) which will see local smaller-scale energy storage supporting the electricity lower voltage Distribution Network. This was a smaller element of SPIRE 1 which has become increasingly important.

6.2.3 SPIRE 2

The SPIRE 2 project is a follow on from the SPIRE 1 project. The project partners acknowledge that while the expansion of centralised, grid-scale storage in the INTERREG region is already underway following the success of the SPIRE 1 project, there has been little progress in the wide-scale deployment of mass-energy storage (MES) which the SPIRE 2 project is based upon.

Variable renewable energy (VRE) resources (e.g. wind and wave) cannot be controlled, and require measures such as energy storage to integrate them into existing power grids. Energy can be stored in bulk using large-scale storage, or at smaller scales using MES devices, owned and operated by domestic and business consumers. MES is crucial to achieving a global transition to clean energy. It allows for optimal use of existing infrastructure, has a less burdensome planning process than large-scale storage, and can be installed rapidly. While progress has been made with large-scale storage, there has been limited development of MES.

SPIRE 2, therefore, aims *"to evaluate, develop and facilitate the wide-scale deployment of MES/Distributed energy storage technologies to operate profitably in new market structures of UK, Northern Ireland and Ireland".*

It will consider how the wide-scale deployment of MES can allow very high levels of renewable energy to be integrated into power grids globally. It will also assess how MES can be used to maximise the whole-life performance of VRE systems operating in harsh environments.

[69] The Department for the Economy acts as Competent Authority for EU Projects of Common Interest (PCIs) where proposed infrastructure falls predominantly or exclusively within NI boundaries. It engages closely with the lead UK Department, the Department for Business, Energy and Industrial Strategy on Member State responsibilities relating to PCIs. Two energy storage projects are currently being progressed in NI under the PCI regime; the Islandmagee Gas Storage project; and a Compressed Air Energy Storage (CAES) project. Separately a third storage project is being delivered by AES Kilroot. AES has delivered a 10MW battery array which it proposes to expand to a 100MW solution. The benefits and services offered by the 10MW facility are currently being assessed by the Transmission System Operator (TSO) and the Regulator to understand the role that storage projects can play. Mass Energy Storage has the potential to contribute to the security of the electricity supply, the integration of renewable generation, the optimal use of the existing infrastructure, and to reduce the need for system constraint payments. One of the key challenges in integrating storage projects with market arrangements is understanding the benefits that storage can play, particularly in the context of a renewables agenda and higher penetration of energy from renewable sources on the grid. A major programme is being led in the all-island wholesale market (SEM) by the Transmission System Operators to inform this thinking.

Complementing the success of SPIRE 1 in establishing the case for grid-scale energy storage, it is anticipated that the SPIRE 2 project will:

- Focus in more detail on the opportunities for storage at the distributed electricity network, industrial, community and domestic consumer level, in the context of new market arrangements;
- Consider opportunities for improving the business models for such technologies through transparent visualisation of new market structures (i-SEM, DS3[70], CfD, Balancing Agreements, etc.).
- Seek to identify new market opportunities and complementary solutions at smaller scales, recognising their advantages in terms of ease of deployment, financing and a faster and less cumbersome planning process;
- Consider grid-scale technologies and electricity network constraints, including the proposed Compressed Air Energy Storage development and the potential for further interconnection at the modelling stage to determine the market capacity for SPIRE 2 products. Thus, an intense market modelling package will address likely market segment sizes, necessary operational characteristics for optimal market participation and cost/benefit constraints.

It is noted that the project partners consider that SPIRE 2 does not offer the potential to displace DS3 for the following reasons:

The Transmission System Operators (TSOs: Eirgrid and SONI) have developed a comprehensive programme (DS3) including management of system frequency response (to deal with a 25% reduction in synchronous inertia); increase in ramping capabilities to meet growing variability and uncertainty in energy sources; reactive power management to deal with system voltage control; and close management of grid code requirements (e.g. contracted level of primary operating reserve during low frequency disturbances).

Currently, the TSOs can securely manage the system provided that the System Non-Synchronous Penetration (SNSP e.g. wind) level in real-time operations remains below 50%. The success of the DS3 programme will lead to an unprecedented SNSP level of 75%. This, together with the planned grid infrastructure investment, will enable Ireland to meet its challenging target of 40% renewable electricity by 2020.

Therefore, DS3 (Delivering a Secure, Sustainable Electricity System) is about developing solutions to the challenges of operating the electricity system in a secure manner while achieving 2020 renewable electricity targets. The SPIRE 2 project partners note that DS3 is not a market structure but may evolve into such as research findings emerge. They consider that the wider the basis of research that can be incorporated into DS3, the more appropriate the market structures will be for all stakeholders. Eirgrid and SONI are part of the SPIRE 2 Advisory Board and will benefit for the SPIRE 2 focus on Energy Storage.

Furthermore, DS3 is a grid services strategy to encourage deployment of technologies to manage very high levels of wind energy (such as energy storage). Conversely, they suggest that Spire 2 is a research and innovation project, designed to maximise the deployment of energy storage. The SPIRE 2 project partners state that DS3 and SPIRE 2 are therefore entirely complementary. DS3 products will provide income streams for mass energy storage as under current market structures there are no mechanisms.

In terms of duplication, the project partners state that SPIRE 2 does not duplicate but, instead, adds to the portfolio of research necessary to shape market structures from the DS3 project. EirGrid research reports that it is supporting projects under categories such as:

Energy and System Services
- AES Kilroot – Battery – Also supported under SPIRE 2 as new market structures need to be integrated along with new aspects of Fast Frequency Response, Ramping products, Fast Post-Fault Active Power;
- Project Batteri – Transport batteries – not directly considered under SPIRE 2.

System Services
- Flywheel/Battery Hybrid demonstration – not considered under SPIRE 2;
- Rotating Stabiliser demonstration – not considered under SPIRE 2.

[70] DS3 (Delivering a Secure, Sustainable Electricity System) is expected to develop a suite of measures to address the challenges of integrating renewable generation onto the power system in a secure manner that can achieve the 2020 renewable energy target. The DS3 programme will help to define a route to market for those projects and will remunerate providers for the services of most value to the grid.

Demand Side

- Real Value – domestic heating – Directly heated water energy storage whereas SPIRE 2 will consider electric-driven heat pumps and heat storage via phase change materials and thermochemical materials;
- Electricity Exchange – use of existing technologies to manage large commercial customer responses to electricity market needs. SPIRE 2 will develop and assess new technologies to complement this activity.

Following a series of consultations with stakeholders (including the Invest NI Energy Storage Group of 15 relevant local businesses and presentations to UK Thermal Energy Storage), the SPIRE 2 project partners agreed that focus should be placed on:

- Renewable energy system performance over time;
- Electricity energy storage technologies;
- Thermal energy storage technologies;
- Electricity network constraints;
- Understand how and where such systems can be deployed; and
- Market implications of the deployment of such technologies.

It is envisaged that the SPIRE 2 will identify a viable pathway for the deployment of optimised energy storage solutions that benefit not only energy utilities, industrial complexes, communities and homes but also electricity transmission operators and distribution system operators and government's attempts to reach sustainability targets.

SPIRE 2 also aims to increase the region's Research and Innovation (R&I) capacity by creating a cross-border Virtual Research Graduate School (VRGS) in the area of Mass Energy Storage (MES). It is anticipated that the project will boost collaboration between Research Institutes and SMEs and intensify technological innovation and commercialisation in the region.

The project intends to recruit and graduate 17 PhD candidates, further develop 6 post-doctoral researchers, and enhance the standing of the academic and industrial teams. The suggested PhD topics are aligned to stakeholder needs.

Ulster University and Dundalk Institute of Technology were the partners in the SPIRE 1 project. SPIRE 2 has further expanded on this partnership with 2 additional universities as well as 14 additional partners. The project is led by Ulster University (UU), which specialises in research project management, electricity market modelling, thermal energy storage and demand-side management. The project's other academic partners include:

Table 6.1: SPIRE 2 Project Partners

No.	Partner name	Abbreviation	Country	Role
Lead	Ulster University	UU	UK/NI	
1.	Queens University Belfast	QUB	UK/NI	Leading on electricity storage and power networks
2.	Strathclyde University	STRATH	UK/Scotland	Leading on the life-cycle assessment of renewable energy in maritime climates
3.	Dundalk Institute of Technology	DkIT	Ireland	Leading on energy storage deployment when associated with variable renewable energy.

The project is also anticipated to involve a number of private sector businesses (including two who are formal project partners (Arbarr Electronics Ltd and Sunamp Ltd), as reflected overleaf.

The project partners consider that the benefit of having non-funded partners on the project is that the outputs and impact of the project will be shared across the full supply chain associated with Mass Energy Storage, across three jurisdictions and two energy markets (Single Electricity Market for Ireland and Northern Ireland and British Electricity Trading Transmission Arrangements (BETTA) and its subsequent Capacity Market, Contracts for Difference and Balancing Arrangements).

They further state that the project also needs to consider further interconnection with European markets. To that end, Electricity and Thermal Energy Storage technologies will be assessed for domestic, commercial, community and industrial applications in current and emerging electricity market structures in order for investment in renewable energy to benefit the region by use of the variable renewable energy when required.

To maximise the dissemination of the benefits of the project, it is structured as follows:

- Electricity generators and retailers (AES (NI), Energia (NI/Ire), SSE (NI, Ire, Scot), ESB (Ire)) supported by QUB, Ulster and Strathclyde;
- Technology companies (B9 (NI), Arbarr (NI), Glen Dimplex (NI), Sunamp (Scot), Climote (Ire)) supported by QUB, Ulster, DkIT;
- Large industrial consumers (PayPal, AFC, (All Ire)) supported by DkIT and Ulster;
- Community energy systems (Causeway Coast and Glens Borough Council, NI) supported by Ulster, QUB and DkIT;
- Rural businesses (Ulster Farmers Union, NI) supported by Ulster, DkIT and QUB;
- Domestic energy users (Community Energy Scotland) supported by Ulster;
- Relevant Advisory Board Members: NIE Networks, UREGNI, SONI, Eirgrid (network operation is represented by SSE – a partner).

Table 6.2: Summary of Structure of the Project

	Partner	Abbreviation	Location	Project Role and Expertise	Anticipated Support offered by Project
Electricity generators and retailers	AES	AES	UK/NI	AES has implemented a large-scale battery (10MWh) with a proposed 100MWh in the future should market conditions prove appropriate. Thus, a combination of monitoring and subsequent operation improvements will be augmented by electricity market modelling of new structures and likely operating benefits.	In cooperation with Ulster (market models) and QUB (market models), academic, PDRA and PhD support will be delivered to develop new market structure understanding and how existing and new energy storage technologies will operate under such new market structures. In addition, in relation to SSE and Energia: SSE in conjunction with STRATH academics, PDRA and PhDs and Ulster (academic and PDRA) will assess the wear characteristics of wind turbines in the first instance and marine concepts later and integrate such lifetime performance into long-term energy storage sizing. In addition, onshore wind turbines in NI and Scotland loose curtailment subsidies and wind farm operators will utilise Ulster academia and PDRA to economically size energy storage options
	SSE	SSE	NI/Ire/Scot	SSE operates the West of Scotland electricity network as well as numerous wind farms in Ireland Northern Ireland and Scotland. The loss of onshore wind curtailment subsidies by 2018 has stimulated a need for integrated electricity storage to store electricity during curtailment periods. Furthermore, their offshore operations have challenging maintenance issues so understanding wind turbine wear in extreme environments and its relationship to the loss in performance and subsequent electricity storage sizing.	
	Energia	Energia	NI/Ire	Energia has been providing electricity and gas to Irish businesses since 1999. Over a quarter of all Irish businesses have chosen Energia as their energy supplier, including more than a third of all Irish SMEs. Thus it has a) both knowledge and interest in new and emerging electricity market structures and b) wishes to expand its portfolio into domestic customers through an understanding of the technical and economic pinch points of network renewable electricity, domestic renewable electricity (e.g. PV), decarbonised heating and insulation levels.	
	ESB	ESB	Ire	Electricity Supply Board (ESB) was established in 1927 as a statutory corporation in the Republic of Ireland under the Electricity (Supply) Act 1927. With a holding of 95%, ESB is majority-owned by the Irish Government. The remaining 5% is held by the trustees of an Employee Share Ownership Plan. ESB operates right across the electricity market: from generation, through transmission and distribution to supply. Thus it brings a wealth of electricity generation, renewable energy, network and storage operation experience and wants greater knowledge of emerging storage technologies and their use in new electricity markets.	
Technology companies	B9	B9	UK/NI	Energy storage and renewable energy developer working in tandem with Causeway Coast and Glens Borough Council to develop an electricity and heat network in the Coleraine area. Such a network will improve energy efficiency for local businesses and the community through moving waste heat etc. and the region will also act as a large scale provider of demand-side management. Thus the community augmented by energy storage will operate in the all-Ireland energy market. Thus knowledge of technologies and new market approaches is required.	In cooperation with CC&GBC and CES, QUB (electricity networks), Ulster (Market Modelling, Heat Networks and Demand-side Management) and DkIT (energy storage integration into businesses), academic, PDRA and PhD support will generate most likely feasible solutions for Coleraine to act as a renewable energy management hub.
	Arbarr Group	Arbarr	UK/NI	Current battery offerings in new and emerging electricity markets shaping new product development that optimises operation in new electricity markets	In cooperation with Ulster (demand-side management at a domestic level), evaluate through academia and PhD supervision, the optimum size of energy storage, when combined with renewable energy and energy efficiency e.g. insulation in households, will be developed and assessed in Ulster's Terrace street. NB This support is also anticipated to apply to Energia.
	Sunamp	Sunamp	UK/Scot	Current thermal storage offerings in new and emerging electricity markets shaping new product development that optimises operation in new electricity markets.	
	Climote	Climote	Ireland	Climote has designed and implemented a remote hub at the very heart of the home. It connects via an inbuilt SIM allowing remote control of all home heating. Therefore can such technology add a layer of electricity market interaction and also can such a control add complexity of for example household renewables, heat pumps and thermal storage.	
	Glen Dimplex	GD	UK/NI	Glen Dimplex is a significant energy storage provider. Heating and hot water represent a significant percentage of the total energy demand in the EU. New building requirements will drive a reduction of space heating requirements, but the Roadmap 2050 considers that 'renewable heating and cooling are vital to decarbonisation'. Glen Dimplex requires evaluation of its more flexible electricity-based heat storage options which allow the medium to be charged at any time, to	

Table 6.2: Summary of Structure of the Project					
	Partner	**Abbreviation**	**Location**	**Project Role and Expertise**	**Anticipated Support offered by Project**
				suit electricity grid conditions, and offers customers control over the release of this heat. It will need to understand their role in new and emerging electricity markets.	
Large industrial consumers	PayPal	PayPal	Ire	The company processes online payments and is a subsidiary of online auction site eBay. The Dundalk operation is engaged in account management, risk management and provide customer support for PayPal's operations in Europe, the Middle East and Africa. In order to address energy costs and to ensure the site remains competitive within the international operations of PayPal, it wants to investigate lower energy costs through energy management, integrated renewable energy and energy storage.	In cooperation with DkIT (energy storage integration into businesses) and Ulster (Demand Side Management), academic, PDRA and PhD support will be given to these companies to build techno-economic cases for energy management, renewable energy and energy storage integrated on to their sites.
	The Authentic Food Company	AFC	Ire	AFC has recently taken over the Heinz factory in Dundalk and in keeping with its corporate values e.g. its Go Green project, its wishes to explore a) energy efficiency and energy management; b) heat recovery and heat storage and c) renewable energy integration. Factory energy data will be generated to start this assessment.	
Community energy systems	Causeway Coast and Glens Borough Council	CC&GBC	UK/NI	CC&GBC is investigating in the development of a heat and electricity network to perform energy efficiency and renewable energy integration at Coleraine town scale. This will reduce energy bills in the region making it more attractive for investment by in addition to the above, incorporating energy storage and demand-side management to operate within new electricity market structures. CC&GBC lead a group of local industries and developer and will provide data on the proposed needs of this scheme to address fits feasibility.	CC&GBC and CES represent community interests which are a key area of distributed mass energy storage. They represent the scale of communities from an individual town of over 25,000 people to individual dwellings. CC&GBC is exploring the development of heat and electricity networks to provide energy management and reduced energy costs within the borough when operated with renewable energy and energy storage in new electricity market structures.
Domestic energy users	Community Energy Scotland	CES	UK Scot	Since the launch of Community Energy Scotland in 2008, they have been involved in supporting over 1400 projects across Scotland including hundreds of micro-generation projects in community buildings and social housing, 6.88 MW of wholly community-owned wind projects installed and is working with over 150 groups on large-scale revenue-generating projects, totalling over 180MW of potential renewable capacity. Thus CES would like to understand the role of energy storage at the domestic and community level and will assist in generating data to understand how new energy storage technologies can operate in current and emerging energy markets.	For CES, SPIRE 2 will address energy storage at a range of scales including community and home level and the integration of such approaches into electricity market structures to understand if such technologies can generate income and savings and for whom. In addition, project staff and PhD scholars will work closely with CES relevant staff to demonstrate SPIRE 2 knowledge and its application to CES operations.
Rural businesses	Ulster Farmers Union	UFU	NI	The UFU takes a close interest in rural affairs and services and works with politicians both in the U.K. and Internationally, and other groups and organisations to advance rural interests. Its mission is to serve its members by promoting and supporting a vibrant and sustainable rural economy where agriculture is secure and pivotal to its future. UFU in Northern Ireland has highlighted the potential of on-farm energy storage and the contribution it would make to load management. Indeed, on-farm storage will allow power delivery at specified peak times. The UFU believes that there has not been enough policy consideration to the concept of storage of small-scale renewable energy in Northern Ireland, or in fact anywhere else in the UK. UFU wishes to have this investigated and will provide access to data to assess this possibility.	Farm-based electricity storage and industrial thermal storage will be assessed by Ulster and QUB academics and PhD students. The advantages of energy storage operations will be explored with provided data and models implemented within the new market structures to assess their long-term viability. NB This support is also anticipated to apply to Glen Dimplex.

As illustrated above, the project has drawn together the key, regional electrical storage and thermal storage academic and industrial participants in thermal storage (GD, Sunamp), electrical storage (B9, Arbarr) and controls (Climote) supported by a range of significant end-users in terms of electricity networks (SSE), electricity suppliers (SSE, Energia, ESB, AES), industrial end-users (AFC, PayPal), community and housing applications (CC&GBC, CES) with anticipated support from the System Operator Northern Ireland (SONI) to exploit the opportunity presented by energy storage.

The SPIRE 2 project partners consider that the further advantages of having both funded and non-funded enterprises as partners are to develop a strong working relationship between academia, industry and the researchers of the project. They anticipate that this will ensure the development of industry-relevant projects that have the potential to generate significant future economic impact. It is further envisaged that such relationships will support future employment opportunities for PDRAs and PhDs with both partner and emerging technology companies, electricity suppliers and network operators. To this end, the research titles for PDRAs and PhDs were developed in conjunction with industry needs:

WP3 Market Models:	1. i-SEM and DS3 Transparency (UU, Energia, AES, SSE, ESB) 2. Interconnected SEM-GB Markets (UU, Energia, AES, SSE, ESB) 3. Energy arbitrage with PV Generation and EV Charging (QUB, Energia) 4. Impact of Electricity Storage on Market and Operational Schedules (QUB, AES) 5. Front-of-meter and/or behind-the-meter market analysis of distributed connected mass energy storage (QUB, Energia, SSE)
For WP4 Energy Storage:	6. Phase Change Material Heat Exchanger Performance (UU, Sunamp) 7. Thermochemical Materials for Thermal Energy storage (UU, Sunamp) 8. Storage to augment the capability of the existing thermal plant (QUB, AES) 9. Thermal storage for commercial operations (Ulster, Glen Dimplex) 10. Domestic Battery Integration with Renewable Energy (Ulster, Arbarr)
WP5: Renewable Energy:	11. Raindrop erosion of hybrid coatings for wind turbines. (STRATH, SSE) 12. Mapping seawater effects on wind turbine material degradation (STRATH, SSE) 13. Modelling hailstone impact on leading edge of wind turbines (STRATH, SSE) 14. Modelling materials maps for tidal turbines (STRATH, SSE) 15. Seawater and biofouling effects for tidal turbines. (STRATH, SSE)
WP6: Implementation	16. Optimisation of Domestic Retrofit versus Electricity Network Control (UU, Energia, Sunamp, CES, Arbarr) 17. Advanced Heat Pumps for Novel Battery Heat Recovery (UU/DkIT, Arbarr) 18. Electrical and Thermal Networks for Renewable Energy Integration and Energy Efficiency (UU, CC&GBC, B9) 19. Big Data Analytics for Small Scale Energy Storage (QUB, ESB) 20. Storage placement and technology mix for power system service provision (QUB, UFU, SSE) 21. District thermal resource control, modelling and trading with integrated variable renewable energy and energy efficiency measures at urban zones (DkIT, Ulster, AFC, PayPal)

The Project Partners note that a Commercialisation Manager will seek to ensure that companies of all sizes will be able to access the extensive portfolio of technologies and early-stage ideas/concepts that are available for licencing or in some cases further collaborative development generated with SPIRE 2. They advise that initially the partner companies will have either exclusive or non- exclusive evaluation licences to allow for a period of time (e.g. six months) to explore further the commercial potential of a particular technology in addition to for example, Ulster University's Easy Access (free of charge) IP licences up to full royalty-bearing commercial licence arrangements.

The SPIRE 2 project partners have developed a series of 'SMART Activity Targets' (see Section 6.4.1 for details) that they anticipate will be achieved through the implementation of 5 technical Work Packages (WPs 2-6). The remaining work packages are WP1 (Project Management) and WP7 (Communications).

1	Management
2	Market Models
3	Technology Development
4	Performance of VRE Sources
5	Application and Implementation
6	Business Models and Standardisation
7	Communication

Key aspects of the 5 technical Work Packages (WPs 3-7) are summarised overleaf:

Table 6.3: Key aspects of the 5 technical Work Packages (WPs 3-7)		
WP	**Aim**	**Task and Activities**
WP 2	Aim - develop models of the new electricity markets to inform investment decisions, inform system operators and governments on the potential benefits of MES; quantify how MES/ distributed energy storage' could benefit the region as a whole.	This will involve a series of sub-tasks that both inform and are informed by WP3, WP4, WP5 and WP6: Actions will include: • **WP 2.1** Scenario research to agree on penetration rates of VRE, conventional generation and VRE management approach. This will establish likely market volumes of distributed energy storage; (Advisory Board and Partners) • **WP 2.2** i-SEM research will create market models for a new all-Ireland market emerging from Q3 2017; characterise relevant services that will operate with energy storage concepts (Advisory Board, UU, QUB, AES (NI), Energia (NI/Ire), SSE (NI, Ire, Scot), ESB (Ire)). • **WP 2.3** UK electricity market modelling of proposed Contracts for Difference changes in 2016 and related balancing agreements to accommodate energy storage will provide UK market structures. (UU, STRATH, Advisory Board, SSE). • **WP 2.4** Distributed energy storage for onshore wind farms with reduced/zero subsidies for curtailment at times of excess electricity generation and the role of energy storage will be investigated (UU, QUB, SSE); • **WP 2.5** DS3 Models (Delivering a Secure, Sustainable Electricity System) will investigate up to 75% VRE penetration on the all-Ireland electricity market. The role and necessary technical and economic performance characteristics of distributed energy storage systems will be evaluated (Advisory Board, UU, QUB, AES (NI), Energia (NI/Ire), SSE (NI, Ire, Scot), ESB (Ire)); • **WP 2.6** Interregional models will link WP 2.2, WP 2.3 and WP 2.5 to generate an overall UK and Ireland model as GB and Ireland are linked with electricity interconnectors. Thus, the overall regional market space for distributed energy storage can be established (All Partners, Advisory Board).
WP3	Aims to optimise existing distributed energy storage technologies for new electricity markets and develop new technologies to achieve greater market penetration.	Subtasks are as follows: • **WP 3.1**: Thermal and Electrical Storage and Electricity Network Constraints for Distributed Operations will ensure that the technology readiness level (TRL) of the state-of-art is understood and that this project moves beyond that, whether in novel development and/or novel use. Integration of market characteristics from WP2 assists in targeting technology solutions that address both market needs and electricity network constraints (QUB, UU, B9 (NI), Arbarr (NI), Sunamp (Sco)). • **WP 3.2**: Phase Change Materials (PCM) and Thermochemical Materials (TCM) Compact Thermal Storage systems will be developed for domestic, community and industrial applications. PCM storage can be significantly improved with novel heat exchanger design. TCM storage requires practical systems to demonstrate successfully its higher heat storage capacity. Laboratory development and testing under real conditions (at Ulster's Terrace Street test facility for example) will generate typical characteristics to be integrated into electricity market models when associated with state of the art heat pumps (electrification of heat) and modelled in terms of network constraint alleviation (UU, QUB, Sunamp (Sco)). • **WP 3.3**: Battery Storage Technologies is well established with a range of Lithium-based technologies having different characteristics depending on the configuration. For distributed energy storage within market structures identified in WP2, lithium technologies will be addressed to match characteristics with new market services and demands. Characteristics of solutions will then be integrated into electricity market models in terms of management of VRE resources and network constraint alleviation. Domestic scale verification will take place at Ulster's Terrace Street facility (UU, QUB, Sunamp (Sco)).

Table 6.3: Key aspects of the 5 technical Work Packages (WPs 3-7)		
WP	**Aim**	**Task and Activities**
WP4	WP4 will quantify the decline in the performance of VRE generators in harsh environmental conditions over their full lifetime and develop whole-life energy storage sizing solutions.	WP4 has the following subtasks: **WP 4.1** will research the impacts of weather and seawater on onshore and offshore wind turbine performance and establish a baseline for performance degradation over time (STRATH, UU, SSE). **WP 4.2** will investigate weather and oceanographic impacts on wind turbines through raindrop erosion of wind turbine blades and the role of hybrid coatings to provide longer-term lifetime performance gains for wind turbines. It will further map seawater effects on wind turbine material degradation and will model hailstone impact on the leading edge of wind turbine blades (STRATH). **WP 4.3** will investigate weather and oceanographic impacts on tidal and wave devices through firstly developing a material map for tidal turbines, understanding the lifetime and economics of materials selection in highly active, stressful, harsh environments and understanding seawater and biofouling effects for tidal turbine performance (STRATH). **WP 4.4** will integrate materials and meteorological maps for improving wind turbine selection and performance i.e. reduced materials costs where applicable. This approach will be linked to energy storage for optimal techno-economic sizing in light of a) reduced/zero-subsidy support and b) limited/affordable maintenance access to offshore wind farms (STRATH (Sco), UU (NI), SSE (NI, Sco, Ire).
WP5	WP5 will identify and evaluate a range of approaches to integrate distributed energy storage systems into industry, communities, rural businesses and homes. This is addressed by WP5 which draws on knowledge of WP5 and both acts upon and serves WP2 (Market Models) and WP3 (Energy Storage).	Subtasks of WP5 are as follows: **WP 5.1** will research Thermal Storage and Battery Applications for domestic, business, community and industrial-scale applications, gathering state-of-the-art examples, contacting selected practitioners, determining techno-economic benefits and establishing any social-behavioural changes that need to be considered for their deployment. Domestic systems will be evaluated at Ulster's Terrace street facility (UU (NI), QUB (NI), Sunamp (Sco), Arbarr (NI), DkIT (Ire), AES (NI), CC&GBC (NI), CES (Sco), B9 (NI), UFU (NI)). **WP 5.2** will utilise specialist EMD software to size community heating and electricity networks for the Coleraine area and will further develop a staged techno-economic implementation plan to address its future deployment (UU, CC&GBC (NI), B9 (NI)). **WP 5.3** will address project-specific industry energy use and rural business energy storage viability by initially obtaining integrated VRE supply data (if installed), energy use data and energy supply tariffs to construct an energy storage opportunity methodology based on the cost and scale of appropriate energy storage. Thus, an investment pathway can be devised (All Partners). **WP 5.4** will develop general sizing methodologies for distributed energy storage in domestic, community, rural and industrial applications based on the availability of VRE and energy tariffs (UU, QUB, STRATH, DkIT).
WP6	WP6 will develop standards for MES/ distributed energy storage and their use these to inform policy/strategy for deployment and create education and research pathways to commercialise technologies and generate new businesses. WP6 will feed into Sections 10 and 11 to facilitate economic growth through a supply of highly educated developers able to transform research ideas into commercial reality.	WP6 will deliver Business Models and Standardisation and its subtasks are follows: • **WP 6.1** will review of relevant standards across all applications of distributed energy storage and understand applicability to the potentially wide range of distributed energy storage technologies (heat, electricity and potentially others) (All Partners). • **WP 6.2** will deliver i-SEM, DS3 and CfD business model interpretation workshops, learning materials for the benefit of regional industries and end-users (QUB, UU, DkIT). • **WP 6.3** how new energy markets will generate energy storage business impacts and given the likely technologies and their costs and what would, for example, Energy Service Companies (ESCOs) or other shared cost models (Transmission System Operators, Distribution System Operators etc.) may assist future deployment (All Partners, Advisory Board).

Table 6.3: Key aspects of the 5 technical Work Packages (WPs 3-7)		
WP	**Aim**	**Task and Activities**
		• **WP 6.4** will then draw much of this activity together via integration of market and standard studies to inform new standards that encompass working business models (All Partners, Advisory Board).

6.2.4 Project Management and Governance

A SPIRE 2 Project Management Committee (PMC) has been established. It comprises the academic partners with a separately organised SPIRE2 Industry Partner Group. The Management Committee meets on a quarterly basis with representatives of the Industry Partner Group (representatives from the 12 enterprises, along with the Local Authority (CC&GBC) and Community Charity (CES)).

The project is being overseen by an Advisory Board (AB) comprising regional government representatives, stakeholders, internationally recognised energy experts and representatives from the system and network operators. The AB will meet with the Project Management Committee bi-annually.

In terms of day-to-day management, the project has appointed a dedicated Project Manager hosted at Ulster University to oversee the running of the project. Their role includes ensuring timely and clear communication between the members of the Management Committee and ensuring that progress indicators are being met and that any issues that are raised are communicated to the Management Committee.

The project manager works closely with the Project Lead and the Commercial Lead who are also based at Ulster University. They also work in close partnership with the work package leads at each of the academic partners to ensure that the individual aspects of the project are progressing as planned.

The Office of Research and Impact (R&I) at Ulster, in conjunction with the Finance and Procurement Departments, is supporting the project in all aspects of governance, finance, procurement, technology transfer and developing legal agreements. The R&I office is providing advice on contractual and legal matters relating to IP developed and will assist with the project exit strategy in sourcing subsequent research funding, and developing research proposals.

6.3 Project Budget

The SPIRE 2 project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €6,462,927.86 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €6,703,245.67, as summarised in the tables below:

Table 6.4: Anticipated Project Costs

Summary Budget	**Total Project Costs (€)**
Staff Costs	2,745,599.01
Office and Administration Costs	1,328,748.23
External Expertise and Services	2,086,899.94
Travel and Accommodation Costs	148,174.71
Equipment Costs	393,827.78
Total	**6,703,245.67**

Table 6.5: Anticipated Project Funding

Funding Sources	**Total Value (€) (Public)**
Cash Contribution (Partner Supplied/other grant)	240,317.81
Government Match Funding	794,173.67
ERDF	5,668,754.19
Total Grant Funding	**6,462,927.86**
Total Project Costs	**6,703,245.67**
Intervention rate (% ERDF)	85%

6.4 Anticipated Project Objectives, Outputs and Results

6.4.1 Objectives

The project objectives are as follows:

- To develop models of the new electricity markets to inform investment decisions, inform system operators and governments on the potential benefits of Mass Energy Storage (MES); quantify how MES could benefit the region as a whole;
- To optimise existing distributed energy storage technologies for new electricity markets and develop new technologies to achieve greater market penetration;
- To quantify the decline in performance of Variable Renewable Energy (VRE) generators in harsh environmental conditions over their full lifetime and develop whole-life energy storage sizing solutions;
- To identify and evaluate a range of approaches to integrate distributed MES systems into industry, communities, rural businesses and homes;
- To develop standards for MES and use these to inform policy/strategy for deployment, create education and research pathways to commercialise technologies and generate new businesses.

The project partners have also established the following SMART Activity Targets:

Table 6.6: SPIRE 2 – Summary of SMART Activity Targets
1. Market Modelling - Develop computer simulation packages to allow advanced modelling of the new electricity markets in GB and Ireland. Use simulations to guide investment decisions for MES; inform system/network operators, energy retailers and government departments on the potential for MES; and quantify how MES could benefit the region as a whole (WP3)
2. Technology Development - Optimise existing MES energy storage technologies for new electricity markets; develop new technologies to achieve greater market penetration (WP4)
3. Whole-life VRE Performance - Quantify the decline in the performance of VRE generators in harsh environmental conditions over their full lifetime; develop whole-life energy storage sizing solutions to align with real-world performance (WP5)
4. MES Integration - Identify and evaluate a range of approaches to integrate MES into industry, communities, rural businesses and homes (WP6)
5. Standards Development – Propose/develop standards for MES; use these to inform policy/strategy for wide-scale MES deployment (WP7)
6. Dissemination and Commercialisation – This will be achieved through the implementation of a Communications Plan (WP2). Create education and research pathways to commercialise technologies and generate new businesses; facilitate economic growth through a supply of highly educated developers able to transform research ideas into commercial reality.

The project partners have provided the following detailed overview of the 6 'SMART Activity Targets':

Table 6.7: Overview of the 6 'SMART Activity Targets'

SAT	Description	Suggested PhD Topics
SAT 1: Market Modelling	SAT 1 is associated with WP3 deliverables, which are anticipated to be delivered in line with the following schedule: 1. Future VRE-penetration scenarios report – month 12 2. Functional model of all-island i-SEM – month 18 3. Functional model of GB electricity market – month 24 4. Modelling distributed storage co-located with onshore wind – month 30 5. DS3 modelling incorporated into i-SEM – month 30 6. Interregional Interconnector modelling – month 36	PhD topics are anticipated to be selected from the following: • P3.1 i-SEM and DS3 Transparency (UU, Energia, AES, SSE, ESB) (Month 36-48) • P3.2 Interconnected SEM-GB Markets (UU, Energia, AES, SSE, ESB) (Month 36-48) • P3.3 Energy arbitrage with PV Generation and EV Charging (QUB, Energia) • P3.4 Impact of Electricity Storage on Market and Operational Schedules (QUB, AES)[71] • P3.5 Front-of-meter and/or behind-the-meter market analysis of distributed-connected mass energy storage (QUB, Energia, SSE).
SAT 2: Technology Development	SAT 2 is associated with WP4, deliverables for which will be delivered in line with the following schedule; 1. Report on Thermal, Electrical Storage and Electricity Network Constraints – month 9 2. Phase change materials (Month 24) and thermochemical materials laboratory development (Month 45) 3. Battery Storage Technologies laboratory development (month 24) and Network Constraints Analysis - month 45.	PhD Topics will be selected from the following: • P4.1 Phase Change Material Heat Exchanger Performance (UU, Sunamp) • P4.2 Thermochemical Materials for Thermal Energy storage (UU, Sunamp) • P4.3 Storage to augment the capability of the existing thermal plant (QUB, AES) • Two further PhD titles TBC
SAT 3: Whole-life VRE Performance	SAT 3 is associated with WP5, deliverables for which will be delivered in line with the following schedule: 1. Review on the state of the art of environmental conditions on Wind Turbine Performance (Month 12); 2. Report on raindrop erosion of hybrid coatings for wind turbines (Month 24); 3. Report on modelling hailstone impact on the leading edge of turbine blades (Month 36); 4. Report on materials maps and seawater and biofouling effects for tidal turbines (month 50); 5. Whole-life analysis and optimization of storage for wind turbines (month 24 to project end).	PhD Topics will be selected from the following: • P5.1 Raindrop erosion of hybrid coatings for wind turbines. (STRATH, SSE) • P5.2 Mapping seawater effects on wind turbine material degradation (STRATH, SSE) • P5.3 Modelling hailstone impact on the leading edge of wind turbines (STRATH, SSE) • P5.4 Modelling materials maps for tidal turbines (STRATH, SSE) • P5.5 Seawater and biofouling effects for tidal turbines. (STRATH, SSE).

[71] It is anticipated that System Operator Northern Ireland (SONI) will support scholarships P3.4 and P3.5 with data.

Table 6.7: Overview of the 6 'SMART Activity Targets'		
SAT	**Description**	**Suggested PhD Topics**
SAT 4: MES Integration	SAT 4 is associated with WP6, deliverables for which will be delivered in line with the following schedule: 1. Thermal Storage and Battery Applications Report (month 12) 2. Community heating and electricity networks and optimal domestic applications report (Month 24) 3. Industry energy use and rural business energy storage viability report (Month 30) 4. Sizing methodologies for distributed energy storage (Month 48)	PhD Topics will be selected from the following: • P6.1 Optimisation of Domestic Retrofit versus Electricity Network Control (UU, Energia, Sunamp, CES, Arbarr) • P6.2 Advanced Heat Pumps for Novel Battery Heat Recovery (UU/DkIT, Arbarr) • P6.3 Electrical and Thermal Networks for Renewable Energy Integration and Energy Efficiency (UU, CC&GBC, B9) • P6.4 Big Data Analytics for Small Scale Energy Storage (QUB, ESB) • P6.5 Storage placement and technology mix for power system service provision (QUB, SSE) • P6.6 District thermal resource control, modelling and trading with integrated variable renewable energy and energy efficiency measures at urban zones (DkIT, AFC, PayPal).
SAT 5: Standards Development	SAT 5 is associated with WP7, deliverables for which will be delivered in line with the following schedule: 1. Review of relevant standards across all applications of MES (Month 12) 2. i-SEM business model interpretation report (Month 24) and Master's degree education modules) (UU with contributions from all partners) 3. New energy markets energy storage business impacts report (Month 36) 4. Integration of market and standard studies to inform new standards (Month 50)	
SAT 6: Dissemination and Commercialisation	SAT 6 has 4 associated sub-targets, which will be delivered in line with the following schedule: 1. Report on potential industrial partners on a global basis (month 12) 2. Report on the most appropriate global markets for the deployment of technologies and services developed in SPIRE 2 (month 18) 3. Preparing a SPIRE 2 'Legacy Business Plan' (month 24) 4. Preparing articles for publication in commercial/industry literature (ongoing from month 6 until the end of the project).	

Table 6.8: Participation summary by SMART Activity Target						
	SAT 1: Market Modelling	**SAT 2: Technology Development**	**SAT 3: Whole-life VRE Performance**	**SAT 4: MES Integration**	**SAT 5: Standards Development**	**SAT 6: Dissemination and Commercialisation**
Lead	Ulster	QUB	STRATH	DkIT	Ulster	Commercialisation Manager
Research	QUB, STRATH,	Ulster, DkIT	Ulster, QUB	Ulster, QUB	DkIT, STRATH, QUB	Ulster, DkIT, STRATH, QUB
Enterprise	AES, SSE, ESB, Energia	Arbarr, Sunamp, B9, GD, Energia, ESB, SSE, AES	B9, Energia, ESB, SSE	B9, Energia, SSE, Arbarr, AES, ESB, Sunamp, AFC, PayPal, UFU, GD, Climote	B9, Energia, SSE, Arbarr, AES, ESB, Sunamp, AFC, PayPal, UFU, GD, Climote	B9, Energia, SSE, Arbarr, AES, ESB, Sunamp, AFC, PayPal, UFU, GD, Climote
Location	NI/WoS/BRoI	NI/WoS/BRoI	WoS/NI	BRoI/WoS/NI	NI/BRoI/WoS	NI/BRoI/WoS
Beneficiaries	Govt. Depts, System Operator, Market Operator, Technology Developers, Energy Companies	System Operator, Market Operator, Technology Developers, Energy Companies	Windfarm Operators; Technology Developers; Energy Companies,	Energy Consumers; System Operator, Market Operator, Technology Developers, Energy Companies	Standards Institutes; System Operator, Market Operator, Technology Developers, Energy Companies	Energy Consumers; Windfarm Operators, Standards Institutes, System Operator, Market Operator, Technology Developers, Energy Companies
Other Partners:				CC&GBC, CES	CC&GBC, CES	

6.4.2 Outputs

Per the Letter of Offer (dated 21st June 2017), the anticipated (approved) SPIRE 2 project outputs are as follows:

Table 6.9: Approved Output Targets

Output Code	Name of Output	Programme Target	Project Target	% of Programme Target	Notes
CO01	Number of enterprises receiving support	20	12	60%	SPIRE 2 will provide combinations of academic, PDRA and PhD support to address the project needs of all partners. It is anticipated that all 12 enterprise partners will receive research support from academic partners. Those enterprises are anticipated to be: • Arbarr Group; • Sunamp; • B9; • Glen Dimplex; • Climote; • AES; • SSE; • Energia; • ESB; • PayPal; • Ulster Farmers Union; • The Authentic Food Company.
CO02	Number of enterprises receiving grants	10	2	20%	Grant support has been allocated to facilitate demonstrations of technologies in the eligible area. Two technology developers were chosen for grant support; Sunamp and Arbarr. • Sunamp is a thermal storage provider (for the electrification of heat), developing novel phase change materials and alternative high-temperature thermochemical materials. It wishes to improve their performance and demonstrate innovative use within UK and Ireland electricity markets; • Arbarr is an electronic and electrical storage company which has developed a number of lithium-based battery solutions and associated charge controllers. Current products will be tested in simulations of new electricity markets. This will suggest charge, discharge and capacity characteristics appropriate to conditions in new electricity markets. Based on these, new battery structures will be developed and evaluated.
CO04	Number of enterprises receiving non-financial support	20	12	60%	All 12 enterprise partners will receive non-financial research support from academic partners.

Table 6.9: Approved Output Targets					
Output Code	**Name of Output**	**Programme Target**	**Project Target**	**% of Programme Target**	**Notes**
CO24	Number of new researchers in supported entities	514	83	16%	SPIRE 2 is anticipated to provide a total of 83 full-time researcher years through 17 full-time PhD students, 8 Post-Doctoral Research Fellows (PDRF) and 13 project academics. • It is anticipated that 17 PhDs will be delivered (16 x 3 person-years and 1 x 4 person-years = 52 person-years in total). • 8 Post-Doctoral Research Associates (PDRA) will deliver 27.65 person-years and will work closely with both industry and academia, delivering innovations, expertise, publications and future income generation. • 13 Project academics will provide significant experience in managing interactions between industry and academic partners, ensuring quality outputs are delivered on time and to budget (3.35 years).
CO26	Number of enterprises cooperating with research institutions	10	12	120%	The 12 enterprises listed in CO01 will cooperate with research institutions. The project partners consider that mass-energy storage technologies need to be adopted by large numbers of energy users including domestic, business and public sector consumers. The research will, therefore, need to engage with a comprehensive range of organisations. SPIRE 2 has amassed partners representing energy suppliers, distributors, end-users and stakeholders who will work with leading academic teams across the region, whose research is complementary to their activities. SPIRE 2 is further supported by an Advisory Board consisting of electricity system operators, network operators, energy suppliers and regulators.
CO41	Number of enterprises participating in cross border, transnational or interregional research projects	10	12	120%	The 12 enterprises included in CO01 will also contribute to the achievement of this output by working on a cross-border or transnational basis. Project implementation will involve transnational evaluations, demonstrations and trials of technology developed through the project. SPIRE 2 will develop 2 novel thermal storage technologies and 1 novel battery technology. It will evaluate their innovative use in i-SEM, DS3 (Ireland) and Contracts for Difference/Balancing Agreements (Scotland), leading to 9 state-of-the-art trials focussing of the role of MES in the eligible area. Demonstrations in domestic applications will address cost issues and develop viable business cases.
CO42	Number of research institutions participating in cross border, transnational or interregional research projects	5	4	80%	The 4 academic partners are University of Ulster, Queens University, Strathclyde University and Dundalk Institute of Technology. The project academic members have representation from the Border Region of Ireland, Northern Ireland and Western Scotland.

6.4.3 Results

SPIRE 2 is anticipated to produce 78 peer-reviewed journal and conference publications, with cross-border authorship, joint industry/academic output, and the potential to create economic impact.

Table 6.10: Anticipated Result Indicator			
Result Indicator	**Programme Target**	**Project Contribution**	**Percentage of Result Indicator**
The annual number of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross border authorship and with the potential to create economic impact.	75	78	104%

The project partners project that the target of 78 will be achieved as follows:

- 37 Journal publications; and
- 41 national, regional and international conference presentations.

The SPIRE 2 Project Partners anticipate that the 'SMART Activity Targets - SATs' will deliver the following Peer-reviewed Journal and Conference Papers with Cross Border Authorship in line with the following schedule.

Table 6.11: Anticipated Achievement of Result Indicator by SAT	
SAT	**Total**
SAT 1	22
SAT 2	16
SAT 3	17
SAT 4	16
SAT 5	7
SAT 6	-
Total	**78**

Suggested journals and conferences are cited as follows:

1. Targeted journals include Energy Policy, IEEE Transactions on Power Delivery, Applied Thermal Engineering, Applied Energy, Renewable Energy, Wind Energy and Tribology International.
2. Targeted conferences include UK Thermal Energy Storage, UK Energy Storage, the International Conference on Tribo-Corrosion, the European Wind Energy Association Conference, and the IEA Heat Pump Conference.

The SPIRE 2 project partners consider that this will boost regional economic development through international recognition of the region as an energy storage innovator and will contribute to attracting major industry interest to both the annual SPIRE 2 workshops and the closing conference.

The project partners have indicated that they intend to follow a 'Green Open Access' route[72] (but will be encouraged to peruse Gold standard Open Access where funding is available[73]), noting the following:

- Green OA is when the author publishes in a journal and then deposits a version of this article into a subject or institutional repository. Most journals comply with Green OA policies. Sherpa/Romeo or Sherpa/Juliette provides compliance information of publisher's self-archiving policies.

[72] Ulster University's Open Access (OA) publishing policy requires all staff to pursue the Green OA Route and self-archive their accepted articles and make these OA via the Ulster Institutional Repository (UIR). Ulster's Research Data Management Policy requires all staff to archive and make the underlying data associated with their research OA in the University's Data Repository to meet the requirements of external funders. The project partners will be encouraged to pursue the Gold OA Route but only if they have secured funding to pay for this from their funder. This costs between £2,000 - £13,000.
[73] NB The project has not established a budget for gold standard.

- Gold OA is when the author makes their article openly accessible in a journal, sometimes for a fee or Article Processing Charge (APC). This journal may be exclusively OA, or it may be a hybrid, with a mixture of OA and subscription-only articles. Sherpa/Fact is a Funders' and Authors' Compliance Tool to help researchers check if their chosen journals comply with their funder's requirements for open access to research.

6.4.4 *Innovation Activity*

SPIRE 2 expects to generate at least eight intellectual property (IP) disclosures in:

1. Phase change material storage;
2. Thermochemical material storage;
3. Compact battery storage;
4. New battery materials usage;
5. Novel heat pump design;
6. Novel materials for wind turbine blades;
7. New biofouling preventative measures;
8. Big data handling solutions.

Each of the SATs and WPs is anticipated to generate innovation and potential commercialisation opportunities. Any IP generated will be managed in accordance with the project's partnership agreement. Arrangements are in place for IP management which covers knowledge management, confidentiality obligations, background, ownership and transfer of ownership of results, protection and exploitation of results, dissemination, access rights and settlement of disputes.

IP will be managed through all stages of the project, with significant input at the proposal stage and will continue through grant preparation, project implementation, exploitation and dissemination of results stage and conclusion of the project.

Costs have been included within the project's budget to manage the process of IP.

UU's Research and Innovation (R&I) office will provide advice on contractual and legal matters relating to IP developed, and will assist with the project exit strategy in sourcing subsequent research funding, and developing research proposals.

6.4.5 *Other Targets*

In addition to the anticipated Results and Outputs featured above, the project partners envisage that the SPIRE 2 project will also produce the following additional deliverables:

- 17 PhD Theses;
- 16 reports.

6.4.6 *Other Suggested 'Expressions' of Impact*

The SPIRE 2 project partners have further suggested that they anticipated that the project will result in the following 'expressions' of impact:

Table 6.12: Other Suggested 'Expressions' of Impact

	Expected Impacts	Impact indicators	Suggested Evidence
Social Impacts	Increased knowledge base at 4th education level	Higher proportion of student population with PhD education	Increased proportion of PhD candidates
	Increased cooperation between industry and academia	Increased hiring of high-level candidates by energy companies	Number of companies participating in industry fora
	Increased opportunities for knowledge-based social mobility	Improvement in graduate prospects from different socio-economic backgrounds	Number of diverse candidates who apply for PhD positions
	Increased awareness of socio-economic aspects of the energy industry	Present to conferences on energy policy	Inclusion of outputs in government policy
	Awareness of energy poverty and causes	Feed into government policy on energy poverty	Inclusion of outputs in government policy
	Addressing overall energy costs in society	The overall decrease over time in energy costs	Newmarket structures reflect energy storage role
	Impacting competitiveness of regional economies	Develop an energy storage industry in NI/ROI/Sco	Companies/spin-outs establishing in the region in the storage
Economic impacts	Develop new industry in energy storage	Companies diversifying/establishing activities in energy storage	New company registrations, new product launches
	Develop IP outputs and supports for commercialisation	Licences or patent disclosures to industries	Financial flow back to academia from industry
	Increased assistance for companies to participate in research	Greater R&D spend by aligned companies	New product development in energy storage
	Direct financial support for some companies increasing their viability	Increased product offering from these companies in energy storage	Sales of new products/services
	Direct knowledge support for companies increasing their viability	Diversification/product/service development in energy storage	Sales of new products/services
	Make grid operators aware of how to decrease the overall cost of energy by using storage	Reference/Inclusion in energy management plans	Business Plans reference project
	Making investment in variable renewable energies more cost-effective by addressing commercial knowledge questions	Increased spend in energy storage technologies in the next 5 years.	VRE investments include energy storage in Cap Ex
Environmental impacts	Awareness of energy storage technology components and contents	Development of non-fossil related energy storage technologies	New product/process developments
	Increased VRE penetration	Incorporation of energy storage into VRE developments	Project design incorporating energy storage
	Increase in efficiency of existing technologies	Reduction in energy wastage and increased efficiency of existing technologies	Technology disclosures from project
	Increased recovery of energy using new technologies	CO2 intensity reduction in electricity production	Reduced regional CO2 emissions
	Development of clean energy storage technologies	CO2 reduction or sequestration during energy storage	New product/process developments
Cooperation impacts	Cross border/interregional authorship of publications	78 peer-reviewed publications and conference presentations	Impact factor, citations, references and h-factor of authors
	Cross border/interregional supervision of students	Jointly supervised research projects sharing knowledge and resources	17 PhD theses completed within project
	Interregional understanding of research questions	Identifying economically important research questions	Participation of industry partners in joint PhD projects
	Interregional development of Post-doctoral research links	Joint publication and research	Publications and future funding applications
	Interregional collaboration between enterprises and academia	8 IP disclosures from project	Licensing agreements with industry, TTO outputs
	Sustained development of further projects by the consortium	Applications for further research and development funding	Recognition of the SPIRE2 project as a research centre by SFI/EPSRC

6.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the SPIRE 2 project's key achievements (as of July 2019) and the extent to which the SPIRE 2 project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

6.5.1 Key Achievements (to July 2019)

Key achievements reported by the SPIRE 2 project partners include:

- The SPIRE 2 project partners report that they have engaged with a wider variety of enterprises than was envisioned at the time of their application for funding.
- The SPIRE 2 Commercialisation Manager has developed a SPIRE 2 Value Proposition and Commercialisation Roadmap template for all PhDs on the SPIRE 2 Project. The Value Proposition is intended to provide a clear statement that explains how the PhD's product (research) solves customers' problems or improves their situation (relevancy), delivers specific benefits (quantified value), tells the ideal customer why they should buy from the PhD and not from the competition (unique differentiation). It is anticipated that typically, the industry stakeholder will be driving this value proposition. It is expected that this exercise will underpin the development of a commercial route map for the research undertaken in SPIRE 2.
- A series of funding applications and proposals have been developed as a direct result of the SPIRE 2 R&D work undertaken, including:
    - EPSRC Lot-NET (Ulster £1.3M) regarding heat storage in thermal networks;
    - H2020 Chester (Ulster 220k Euro) where heat pumps are developed for high-temperature storage applications.
    - Two proposals were submitted i.e. Interreg V FASTER where Ulster will deploy and evaluate EV chargers in NI if successful.

However, the project partners also report encountering some challenges, including:

- The main challenge and risk to the project had been recruiting sufficient suitable PhD students, with the project partners noting that the marketplace had been very competitive. To mitigate the risk the HE Institutions adopted a continuous recruitment approach rather than recruiting in cohorts. It is understood that all of the anticipated PhDs were in place by Quarter 7 (1st September 2018 – 30th November 2018).
- At November 2018, Authentic Food Company closed and as a result withdrew from the project. Consequently, the SPIRE 2 project management team had to secure a new partner for the stakeholder group.
- Securing real-time data was proving problematic. The project was continuing to resource internal solutions to provide data for example through the Ulster test houses, NIHE HandiHeat project and potential CASE funded projects where data could be forthcoming.
- The SPIRE 2 Lead Partner in consultation with SPIRE 2 partners revisited the Project Management plan to reflect partner concerns that the process was difficult to manage and track progress on the project through the capture of the key activities and deliverables. The team have attempted to streamline the number of deliverables and also map these deliverables and associated activities and WPs to the Output Indicators and results. This is an iterative process with full partner participation.
- The project partners further note that changes within the energy marketplace and political landscape including Brexit, I-SEM, DS3, Interconnection will be mapped into the PhD programme and reflected in the revised project management plan.

- The partners note that energy storage is a very strong growth area that is moving quickly. Whilst this is positives are there is no shortage of engagement, the negative is that PhDs are a quasi-defined programme of work which is not always responsive to the immediate short-term needs of the industry. The partners suggest that ***"any new programme may wish to consider a combination of PhD qualified researchers and PhD scholars to address shorter-term research challenges allowing the PhD scholars to address longer-term issues".***

The SPIRE 2 project partners indicate that they sought agreement from SEUPB to amend and modify their Output Indicators (CO) relating to the Enterprise Engagement process and to restructure their Project Management Plan with amendments to work packages, activities and deliverables. They suggest that this was necessary in order to provide the project partners *"with the latitude to deliver on the project outputs and COs".*

The SPIRE 2 project partners also cite the project's key achievements (as of February 2019) as being:

Table 6.13: Key Achievements		
Period	**Dates**	**Key Achievements**
1	1st March 2017 – 31st May 2017	• UU delivered with aid of partners: - A renewable energy scenarios report, and met with energy regulators, Eirgrid and Northern Ireland Electricity Networks; - A GB electricity model; - Both thermal and electrical demand-side management test facilities were integrated into its Terrace Street house project; - A CAES review. • QUB led on network constraints and energy storage technology reporting and in particular battery storage aspects and Electricity Network Constraints challenges. They worked with AES on large scale battery operations. • Strathclyde University began to report on weather and offshore impacts on wind turbine performance. It was anticipated that this would include a literature review on raindrop erosion on wind turbine blades, material challenges and a tidal turbine overview. • DkIT documented its experiences with Flow batteries and Thermal Storage. These facilities are evaluated in-situ on the DkIT campus operating with their large-scale wind turbine. Preliminary research was undertaken relating to how a LIDAR might assist in the optimal siting of wind turbines in complex terrains. DkIT's partnerships in International Energy Agency tasks facilitated engagement with standards organisations as they started to determine how energy storage standards could be developed. • Arbarr delivered a battery to UU's Terrace Street for testing with both Photovoltaics (PV) and ultimately with electricity network (grid) connection. Operations with PV had proved successful to date. • Sunamp had discussions with UU regarding the installation of a Sunamp Stack in one of its Terrace street test houses. It was anticipated that this would occur after UU had completed its baseline tests with its Daikin high-temperature heat pump and hot water store. • Meetings with enterprises and stakeholders were initiated.
2	1st June 2017 – 31st August 2017	Ulster University • Developed PLEXOS Energy Market Models for the Singe Electricity Market. This ensured that with current data, the model could be verified and act as a basis for future modelling. The same model was extended to understand the role of the current Moyle Interconnector between Northern Ireland and Scotland. It illustrated under-utilisation in trading due to local electricity network constraints in Northern Ireland. • Completed baseline tests for a heat pump and thermal storage (water) with high losses from traditional thermal storage.

Table 6.13: Key Achievements		
Period	**Dates**	**Key Achievements**
		• A report on concepts for Causeway Coast and Glens Borough Council heat and electricity networks was presented. Large scale energy storage and domestic energy storage reviews were provided. <u>QUB</u> • Developed Energy Market Models for the Single Electricity Market, focussing on wider interconnection studies and gas-to-power possibilities. • A wind curtailment study was completed. <u>University of Strathclyde</u> • Studied hailstone impact which was thought to be a key factor in the leading-edge erosion and damage of the composite materials of wind turbine blades. Using UK meteorological data, it was demonstrated that rotational speed is a crucial factor in determining the magnitude of the kinetic energy associated with singular impact and was likely to be significant for incidents of hail. <u>DkIT</u> • Met with The Authentic Food Company and National Pen. <u>Arbarr</u> • Met with Ulster regarding battery improvements and vehicles to grid developments. <u>Sunamp</u> • Was awaiting Ulster's tests to complete in order to install PCM base thermal storage.
3	1st September 2017 – 30th November 2017	• The following activities (some referred to above) were completed: - PCM review; - Testing heat pump and thermal storage operations at domestic scales. Controls related to Electricity market signals have been developed. - Heating networks development; - Battery and Thermal Storage Applications; - Electricity Market Modelling; - Future Energy Scenarios report; - SPIRE 2 Launch; - SPIRE 2 Website and Social Media Accounts; - SPIRE 2 Steering Committee Formulation and Meeting. • 1 PhD student was appointed and commenced work. • 1 paper was accepted for publication (cross border between DkIT and Ulster). • QUB commenced a review of the first draft of the Renewable Energy Future Penetration Scenario Report for discussion. Its development was anticipated to better inform the research questions. • A detailed review was completed of meteorological maps in the UK for the tribological variables such as raindrop size, concentration, hail size, concentration and composition. • DkIT submitted a number of joint publications for international reference.
4	1st January 2018 – 28th February 2018	• The Partners continued to deliver on energy storage market models, technologies, impacts on variable renewable energy resources, implementation and business models; • QUB recruited 3 PhD students and were working with industrial partners to tailor the remaining two PhD projects prior to re-advertising;

Table 6.13: Key Achievements		
Period	**Dates**	**Key Achievements**
		• QUB prepared a journal publication and a conference publication; • Strathclyde concentrated on evaluating the raindrop erosion effects on wind turbines. Strathclyde was also evaluating erosion effects in tidal turbine environments. • Two papers (journal submissions) had been generated; • DkIT saw the delivery of a number of outputs including: - One published journal publication WPT4, two draft journal publications WPT5; - Two poster submissions for delivery in Q5, WPT4; - Successful delivery of the LIDAR system which was a large capital item, WPT4. - Supported a number of local companies in their efforts in developing energy storage projects. • Arbarr became a founder member of the Power and Water Partnership, an Invest NI backed consortium of SMEs working together to exploit potential market opportunities within the power and water sectors. Businesses that Arbarr was working alongside on this project included: Advance Controls, TES, Saliis, B9, Organic Power, Ulster University, South West College and Nitronica. Work was ongoing on a scoping study looking at the viability of an independent commercial operation jointly owned by the member companies to enable market opportunities to be realised; • Sunamp was in discussion with UU over benefits of Sunamp systems among other thermal storage technologies. Discussions also focused on technical details of their technology and of the unit to be provided to the project.
5	1st March 2018 – 31st May 2018	<u>Ulster University</u> • 2 x PhDs were recruited and started (3 further PhDs were recruited with June 2018 start dates; 1 x PhD recruited with a September 2018 start date). • International engagement with Empowered Pty (Botswana) and Botswana International University of Science and Technology on Off-Grid Rural Electrification and Storage Projects in Africa; • Direct project engagement with SPIRE 2 stakeholders Dimplex and Energia centred on developing Cos; • MSc Energy Storage modules preparation and development; • T1 - SEM Paper Submission and Draft Paper outline on: - Interconnectors; - Storage and Interconnectors; - EU Target Model v Brexit Markets. <u>QUB:</u> • Two Research Fellow (RF) posts advertised, shortlisted, interviewed and appointments made with the first post starting 1st June 2018; • One further PhD studentship filled during this quarter bringing the total appointed to 4 with one post to be re-advertised; • Two PhD students started in March and April respectively and were producing deliverables; • Enterprise engagement across AES, SONI/Eirgrid with 2 x PhDs • International engagement on energy storage with China through Sichuan University. <u>DkIT</u> • Attended and presented at 3 conferences (Newcastle, Glasgow Dusseldorf) and submitted 1 publication;

<table>
<tr><th colspan="3">Table 6.13: Key Achievements</th></tr>
<tr><th>Period</th><th>Dates</th><th>Key Achievements</th></tr>
<tr><td></td><td></td><td>Stakeholder engagement with AFC, Louth Council, PayPal, Kilsaran, Great Northern Distillery, Oriel Park etc.
<u>University of Strathclyde</u>
Evaluation of raindrop erosion of wind turbine blades in seawater and in environments affected by seawater and acid rain in whirling arm raindrop erosion rig;
1 x journal paper submitted;
1 x PhD appointed;
1 x joint PhD with DkIT.</td></tr>
<tr><td>6</td><td>1st June 2018 – 31st August 2018</td><td><u>Ulster University</u>
Invest NI and SPIRE2 Energy Industry Day held;
Review of SPIRE 2 Output Indicators and enterprise engagement process;
5 PhDs were fully engaged at UU on SPIRE 2 with final PhD anticipated to start during September 2018;
Ulster Innovate UK ISCF bid submission on SPIRE 2 themed energy storage demonstrator.
<u>QUB</u>
Second PhD PDRF took up post 20th August 2018;
Third PhD student took up post 2nd July 2018;
Fourth PhD student confirmed start date Oct 2018;
Fifth PhD student offered to an international student;
WP 2 was being progressed across 3 PhDs and 2 PDRAs.
<u>DkIT</u>
PDRA was preparing publication in collaboration with QUB with a view to submission in Q4 2018. PDRA also prepared a report on small wind turbine and energy storage standards for a company LGT -SES.
DkIT continued to work towards getting a met mast deployed on a site close to DkIT campus. This had involved significant licencing negotiations.
DkIT developed a number of relationships with local companies, with the progress through interaction phases formalised in the Industry Engagement Plan template which was then used for all SPIRE 2 company interactions.
The first progression to stage 4 of the plan which denotes a successful further leveraging of SPIRE 2 activity to develop a newly funded project was successful with the confirmation by the SEAI in August 2018 of support for the Research Demonstration and Development funded project "Dundalk Virtual Energy Microgrid" which was a joint project between DkIT and Energy Trading Ireland, based in NI.
<u>University of Strathclyde</u>
University of Strathclyde continued to develop research, letters and publications in Journal of Bio-and Tribo-Corrosion across 3 areas.</td></tr>
<tr><td>7</td><td>1st September 2018 – 30th November 2018</td><td><u>Ulster University</u>
Amendments to Output Indicators (CO) Enterprise Engagement process. Adopted by all partners. This led to a restructure of the SPIRE 2 Project Management plan with amendments to WP, Activities and Deliverables. Providing partners with latitude to deliver on meaningful project outputs and COs.
Funding applications and proposal developed as a result of R&D work undertaken.</td></tr>
</table>

Table 6.13: Key Achievements		
Period	**Dates**	**Key Achievements**
		• SPIRE 2 dissemination included Future Energy in NI, NI Energy Forum. Hosted Helen McEntee Ireland Minister for European Affairs at Ulster campus with a tour of SPIRE 2 facilities. QUB • Application to EPSRC Industrial Cooperative Awards in Science and Technology (CASE) provides funding for PhD studentships where the business (SSE) takes the lead in arranging projects with an academic partner of choice. • Extensive work across WP 2 Market Models and WP 3 Technology Development with QUB PhD students. • NEPLAN Training for PhD students. DkIT • DkIT/CREDIT liaising with industry across enterprise engagements. • Development of publications, conferences and dissemination activities. • Supporting the restructured PM plan across partners. • Development of the animation video for SPIRE 2 with UU. University of Strathclyde: • 5 PhDs appointed with one joint PhD with DkIT. • EPSCRC CAMREG IDEAS factory event with UoE. • Scoping SSE engagement. Arbarr • Ulster engagement across the newly started PhDs with project definition ongoing; • Arbarr recruited to the new Power and Water strategic industry cluster with strong potential for storage projects. • Attended Ulster SPIRE 2 Future Energy in NI event and presented at Invest NI Water Industry Sector event. • Funding applications and proposal developed as a result of the R&D work undertaken.
8	1st December 2018 – 28th February 2019	Ulster • Progress on WP Battery Storage Technologies Lab Development. • Project Management Committee in cooperation with the SPIRE 2 Scientific Committee developed bespoke Training and Networking Plans and Career Development Plans for all PhD students; • MSc Energy Storage at Ulster Prospectus developed and opened for applications. • SPIRE 2 stakeholder engagements across Dimplex, Climote, ESB/NIE, Kingspan, Continu, Sunamp, Arbarr, UFU, Siemens, PowerOn, Taggart Architects. • 3 x CASE funding applications Stage 1 with energy storage themes from Ulster. • Journal publications and conference abstracts. QUB • The 5th PhD student took up the post on 7th January 2019. • 2 x Expressions of Interest at Stage 1 were submitted for DfE funded CASE projects which are progressing to full proposals. • 1 x application for a CASE EPSRC project was successful.

Table 6.13: Key Achievements		
Period	**Dates**	**Key Achievements**
		Strathclyde • Erosion projects on materials for wind turbines and tidal turbines continue. Raindrop erosion rig designed for high-velocity testing. • 2 x journal papers accepted in Tribology Transaction and in Journal of Trib-Corrosion. • Preparation for All-Energy Glasgow 2019. • EPSRC CAMREG Ideas Factory event. • Preparation for PhD Networking Day 30th April 2019. SSE engagement to support CO. DkIT: • Progress across 2 x CO activity with Energy Trading Ireland and Ulster Farmers Union. • SPIRE 2 storyboard support on the animation with Big Dog Productions. • Abstracts for posters Dusseldorf IRES 2019. IEA Wind Task 27 and 41 plus IEC TC 88 and IEC120 meetings and reporting. Arbarr: • Discussions with industry on Power and Water partnership cluster. • Ongoing Power Silo R&D work. • AD and energy trading sector discussions. • Off-Grid Street Lighting Battery project tender in ROI. Large scale storage scoping for 100kW turbines.

6.5.2 *Progress towards the Project's Output Indicators*

Table 6.14 provides a high-level summary of the progress that has been made by the SPIRE 2 project towards its Output Indicators.

Table 6.14: Progress towards the Output Targets

Output Code	Name of Output	Programme Target	Project Target	Progress (at July 2019)	Notes
CO01	Number of enterprises receiving support	20	12	In excess of 12	Proceeding according to work plan and progress ongoing. See notes in Table 6.15 for further details.
CO02	Number of enterprises receiving grants	10	2	2	Proceeding according to work plan and progress ongoing. Two businesses (Arbarr and Sunamp) have been allocated grants.
CO04	Number of enterprises receiving non-financial support	20	12	In excess of 12	Proceeding according to the work plan. As per CO01
CO24	Number of new researchers in supported entities	514	83	29.81	NB Forecast to deliver less than 83, due to QUB PhD exiting the SPIRE 2 project (to take up full-time employment), but state that the overall project objectives should not be adversely affected. The project partners suggest that it unlikely that a new studentship will be advertised for SPIRE 2 at QUB, as it is too late to offer a 3-year PhD. However, they note that there are a number of options available to the project to address the shortfall in PhD FTE. It is possible that another PhD may be available at QUB but this would depend on agreement from QUB that the student would be funded from other resources, beyond the end of SPIRE 2. Another solution would be to extend the current researchers or perhaps recruit an additional researcher. This would have to be done with the agreement of the SEUPB as it would require a change to the budget. The project partners indicate that they are actively reviewing options but these will not be resolved until the new academic year starts.
CO26	Number of enterprises cooperating with research institutions	10	12	In excess of 12	Proceeding according to the work plan. As per CO01
CO41	Number of enterprises participating in cross border, transnational or interregional research projects	10	12	In excess of 12	Proceeding according to the work plan. As per CO01
CO42	Number of research institutions participating in cross border, transnational or interregional research projects	5	4	4	Proceeding according to the work plan. Ulster, QUB, Strathclyde and DkIT are participating in cross border, transnational or interregional research projects.

Table 6.15: Notes on Achievement of CO01 (at July 2019)
1. Arbarr: Arbarr has used the SPIRE 2 project to acquire critical humidity and temperature environmental cycling battery testing equipment to facilitate high accuracy temperature, current and voltage measurement and data logging measurements. The design and construction of an automated monitoring and control chamber will facilitate the extrapolation of life cycling data against proof models; and measure the impact of variation of charge rate, discharge rate, depth of discharge and ambient temperature. Ongoing. 2. Sunamp: Sunamps super compact heat battery unit is being tested in the SPIRE 2 /Ulster test houses and projects to assess the scalability of domestic deployment is being carried out. SPIRE 2 PhDs are also modelling new innovative PCM materials to compare with the Sunamp spec. 3. Ulster Farmer Union (UFU): DkIT SPIRE 2 team are modelling the wind farm profiles for individual farms to maximise their availability for grid purposes and standalone battery applications. 4. Glen Dimplex (GD): SPIRE 2 and Dimplex working collaboratively on modelling report of three UK & RoI electric storage scenarios to use as supporting evidence in several Electrification of Heat and SAP working groups. 5. Energia/Power NI: See 12 below. Power NI is the retail arm of Energia and will be involved in the scoping study with NIHE and SPIRE 2. Power NI will deliver on tariff development through the project. 6. B9 Energy Storage: SPIRE 2 leveraged R&D project with partners Ulster University on the Foyle River Gardens Intelligent Sustainable Integrated Energy Management System partnered with Brook Hall Estate (NI) and QUB. CASE funded project. Ongoing. 7. SSE: a) University of Strathclyde SPIRE 2 leveraged project work on erosion models of wind turbine blades. b) QUB and SPIRE 2 have successfully leveraged an EPSRC Case studentship award with SSE on Future Retail Electricity Market Structure and Operations with Increasing Customer Engagement. This entails a full collaboration agreement between QUB and SSE. 8. PayPal: DkIT ongoing energy monitoring and analysis of usage profiles. 9. ESB/NIEN: SPIRE 2 PhDs are fully engaged with NIEN across multiple projects and PhDs. See comments below in Key Questions 10. AES: QUB SPIRE 2 team have been working with AES on grid-scale battery systems to assess and measure voltage and power quality fluctuations. AES company have been taken over in the interim and this ongoing relationship must be assessed in the coming months. 11. Authentic Food Company (AFC): DkIT SPIRE 2 team have been modelling AFC energy usage patterns with a view to implementing an energy storage strategy through SPIRE 2. AFC went into administration and DkIt are pursuing the parent company in the UK to assess if the data and work to date can be usefully extrapolated for SPIRE 2 purposes. 12. Climote: SPIRE 2 has been working closely with the NIHE stakeholder panel to develop a project to utilise 20 No. NIHE homes to trial energy storage battery systems for reducing energy and electricity costs. The panel includes NIE Networks, NU Utility Regulator, NI Consumer Council, SPIRE 2, Power NI (retail arm of Energia) and Climote. Climote will deploy and trial their smart heater device. The aim of this collaborative network is to complete a scoping study to consider the market, economics, technical and commercial challenges for establishing a product and bring domestic battery storage systems to NI residential sector. High impact for SPIRE 2. 13. CONTINU and NI Water: SPIRE 2 leveraged R&D project AQUAFLEX with partners Ulster University, Schneider Electric (UK), NI Water and Grid Beyond (ROI) to examine the potential for consumer-owned battery energy storage systems located at NI Water sites and development of value capture models. Continu is a Belfast-based SME who design, procure, install and maintain UPS for client companies with critical electrical loads (BT, NIE Networks, Apple, NI Water, etc). The company is interested in expanding its offering to include battery energy storage but needs to develop research capacity in this area. Following a series of meetings with the company SPIRE 2 established that there was potential to develop projects with its existing customer base, in particular with NI Water. NI Water is the water utility company for NI, with over 3,000 individual sites and total annual electricity demand of 280 GWh. NI Water is interested in replacing its current diesel-fired back-up plant with a clean alternative, distributed battery storage systems (100s kW to 1-2 MW scale). SPIRE 2, Continu, NI Water formed a consortium (along with Schneider Electric as technology provider and Grid Beyond as an aggregator) to submit a bid to Invest NI through CASE. The Aquaflex bid (for £180,000) was successful and will support a 2-year PDRA post to examine the techno-economic case for battery storage at several exemplary sites. A true cross border enterprise collaboration leveraged through SPIRE 2. 14. Energy Trading Ireland: DkIT Community Energy project called Dundalk Virtual Energy Microgrid (DVEM) leveraged through SPIRE 2 and funded by SEAI.

Table 6.15: Notes on Achievement of CO01 (at July 2019)
15. Power On: Power On through the GIRONA Collaborative Network is submitting a grid/energy storage funding bid through the Innovate UK programme with Ulster as a research partner on SPIRE 2 community energy storage themed activities. Ongoing. 16. SONI/EirGrid: SPIRE 2 is engaging with the System Operator NI (SONI) through QUB and Ulster across several PhDs. 17. NI Utility Regulator (NIUR): NIUR is on the SPIRE 2 steering committee; also, the UR, as a non-ministerial department, is in a uniquely important position in the absence of the assembly. Also, the UR is currently developing its strategy for the energy transition (4 Ds agenda); SPIRE 2 work is directly informing that across the energy storage theme utilising PhDs and academics from across the partnership. Additionally, part of the NIUR's statutory duties includes incentivising innovation. 18. WDR & RT Taggart Ltd: SPIRE 2 leveraged R&D project on Community Energy from Solar Envelope Architecture (CE-SEA) project with partners dPSun (UK), McAvoy Group (NI) and SolaForm Ltd (NI). CASE funded research. Ongoing. 19. Kingspan: Scoping an R&D project on seasonal energy storage with SPIRE 2 partners. 20. NIHE: SPIRE 2 is partnering with NIHE, the largest social housing landlord in NI in the NPA-funded Handiheat project. Handiheat focuses on energy networks for rural communities such as housing, both social and private, which are subject to fuel inequity/poverty and reliant on imported fossil fuels for energy. The development of community energy systems will increase the vitality of rural businesses and lead to a reduction in fuel inequity for those identified as vulnerable. It is aimed at identified opportunities for example to identify anaerobic digestion feedstocks and other underutilised local energy resources. While SPIRE 2 is not a directly funded partner, SPIRE 2 researchers are using data from NIHE houses to assess the effectiveness and cost-efficiency of energy storage in alleviating the risk of fuel poverty. 68% of NI homes are heated by oil, identified as the primary cause of fuel poverty. Houses involved in the Handiheat project will be retrofitted with electrical/hybrid heating systems and thermal/electrical storage systems. The project data will be used by SPIRE 2 researchers to help deliver SPIRE 2 outputs by defining the technical and cost parameters of energy storage systems suitable for wide-scale deployment in social housing. Stakeholders featured from 13-20 were not on original stakeholder list – these would/could constitute new SPIRE 2 enterprise partnerships.

6.5.3 *Progress towards the Project's Result Indicator Targets*

Per Table 6.16, it is anticipated that the SPIRE 2 Project would contribute 78 peer-reviewed journal and conference publications with cross-border authorship.

Table 6.16: Progress towards Result Indicator Targets			
Result Indicator	**Programme Target**	**Project Target**	**Actual as at July 2019**
The number of peer-reviewed journal and conference publications in two target sectors (Renewable Energy and Health & Life Sciences) with cross border authorship and the potential to create economic impact	75	78	15 SPIRE 2 non-cross border 6 SPIRE 2 cross border

In terms of any potential that the SPIRE 2 project might not achieve its result indicator target by the end of the project period, the project partners note the following (at July 2019):

- SPIRE 2 has 17 PhDs, with supporting researchers and academics. It is a 5-year programme with the expectation of 2 conference publications from the PhD researchers and 2 publications per year per academic team over 5 years. The project partners consider that this general target is achievable.
- However, they note that while they expect to deliver 78 publications, they suggest that

  "It is altogether probable that we will not deliver on 78 peer-reviewed cross border publications. The reasons for this are multi-dimensional with the major contributing factor being that SPIRE 2 has only one cross border academic partner (DkIT) and only one PhD contracted in DkIT.

  An associated issue with cross border publications is the REF peer review system at universities which places demands on the quality and impact of the research publication as well as critical research protocols.

To address this ongoing work with NIE Networks (wholly owned by SPIRE 2 stakeholders ESB). SPIRE 2 is accessing NIEN data to support several of the SPIRE 2 PhDs project work in the field of networks and electricity systems operation with storage. ESB run on an all-island basis with a policy of cross border cooperation on R&D. Research conducted by SPIRE 2 accessing NIEN data will inform ESB's work across the island on the Integrated Single Electricity Market (iSEM). It should reasonably be assumed that SPIRE 2 work with NIEN is entirely cross border and co-authoring of papers from NIEN staff should comply with cross border publications. This will support the result indicator targets. In addition, SPIRE 2 staff are working across other border institutes and enterprises to address the challenges posed by a lack of border-based entities".

6.5.4 *Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives*

The Project Partners advise that the project has encountered a number of issues in the delivery of the SPIRE 2 project to date. Specific issues identified by the Project Partners include:

- **Changes to industrial partners -** The Project Partners note that two industry members have left the SPIRE 2 project (AES Ireland discontinued its engagement in the project as a result of the sale of the Ballylumford site and the Authentic Food Company ceased trading). The Project Partners note that they are continuing to engage with potential new businesses to address the loss of these industry partners;

- **Businesses' concerns relating to the loss of background IP -** During consultation, the project partners noted that there have been delays in a number of industry partners engaging with the project due to concerns relating to the potential loss of background IP and the subsequent impact that it would have on their relative competitiveness;

- **Delays in the recruitment of PhD students** to support project delivery - Consultation with the Project's Partners indicate that there were delays in the recruitment of PhD students (it is noted that the last PhD student was appointed during January 2019) to the project. The Project's Partners suggest that this situation may have arisen due to the fact that a number of different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the Renewable Energy sector. This inadvertently created significant demand within the market for these students at the same time, resulting in a shortage of available students and, by association, delays in recruitment;

- **Student mobility issues** – Whilst not deemed to be a significant issue, the Project Partners note that they have faced some minor difficulties in non-EU resident PhD students travelling outside their country of research residence; and

- **EU and SEUPB Procurement requirements hindering the progression of research -** According to one of the project's partners, the progression of research has been hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed to conduct research.

6.6 Best Practice and Learning

In terms of whether the SPIRE 2 project has resulted in any areas of best practice and learning, the project partners note the following:

- Engagement with policymakers is helping to ensure that the project is demonstrating benefits in order to overcome barriers to technology deployments;
- SPIRE 2 is building strong partnerships with existing and new stakeholders to progress the legacy of the mass-energy storage research agenda. Funding programmes like Innovate UK, EPSRC and CASE have been successfully leveraged to support funded R&D to take the research topics and strategies formulated in SPIRE 2 and advance them to maturity and potential commercialisation pathways;
- SPIRE 2 is utilising the research base generated through the project partners to leverage multiple additional funding programmes and in turn encourage extra stakeholders to join the SPIRE 2 'journey'; and

- SPIRE 2 has developed a unique Enterprise Engagement process to track collaborative activity which could lead to meaningful collaboration.

6.7 Synergies between Projects funded

Specific examples of synergies cited by the project partners include:

- SPIRE 2, Bryden, Renewable Engine are working closely together with the Advanced Forming Research Centre (AFRC) at University of Strathclyde, Energy Technology Partnership (Scotland) and CASE (NI) in delivering regular joint showcasing and presentations of the PhD work in renewables and energy storage at events such as All-Energy Conference and Exhibition in Glasgow. The event in 2019 was deemed by the Project Partners to have been a major success with several SPIRE 2 presentations being made in collaboration with both Bryden and Renewable Engine. Preparations are underway for the Innovation Zone showcase at All-Energy in 2020;

- Discussions are ongoing between SPIRE 2 and the Bryden Centre project to identify opportunities for joint PhD training;

- SPIRE 2 PhDs, academics and staff are regular attendees at cross energy conferences and events in NI. Organised events are frequently attended across the three projects;

- SPIRE 2 management team at Ulster works closely with the co-located ECME and Centre for Personalised Medicine staff across common Doctoral College activities including generic training and development of PhDs and in delivering on the Marie Curie principles for research; and

- SPIRE 2 Commercialisation Manager is a board member of Centre for Sustainable Energy (CASE) whose Director is a board member of Bryden and fellow board members are members of Bryden and Renewable Engine. Regular quarterly meetings to address common projects.

6.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the SPIRE 2 project's collaborative and partnership working including:

- The effectiveness and added value of the SPIRE 2 project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

The project partners note that the eligible region features two energy markets, three jurisdictions, different devolved government approaches and policy differences at the national level. Therefore, they suggest that taking a common solution to the wide-scale integration of variable non-dispatchable renewable energy i.e. energy storage and integrating it across all these options requires cross-border co-operation to overcome local techno-economic barriers.

The project partners note that while the eligible area as a whole has sufficient research and innovation capacity to create a technology hub with the capability of conducting and commercialising MES research on the scale proposed, it is geographically dispersed over a wide area and spread between three jurisdictions. They consider that no single region within the eligible area could generate enough critical mass on its own to create the virtual R&I centre that has been developed through the SPIRE 2 project. They note that it has required trans-national/-regional funding focussed specifically on the Interreg area to allow sufficient academic and industry partners to come together to form the SPIRE 2 creative cluster and build innovative capacity within the region.

They suggest that SPIRE 2 is going considerably beyond the pre-existing research provision of the partnering institutions and enterprises, and are of the view that the emerging new market structures, the intense variability of the renewable energy resources, the potential inversion of the existing electricity network (from centralised to more decentralised as renewable energy resources tend to be in more remote locations) and the broad diversity of energy storage technologies means that a breadth of expertise of academic and industry partners is required. However, the skill sets to successfully deliver

such a programme of understanding of how MES can be deployed effectively are not found within one institution or organisation with sufficient depth of expertise to address the many nuances of this integrated picture. The project partners state that in the absence of INTERREG funding, it would not have been possible to bring together such a diverse team of academic and industrial experts who are committed to energy storage deployment as a necessary step in the transition to clean energy.
The SPIRE 2 project partners further note that they are implementing a number of activities to enhance the effectiveness of cross border collaboration in relation to the specific objectives and new ways of working that would otherwise not be possible in the absence of INTERREG V. These include:

<table>
<tr><td>Joint Development</td><td>This project has been jointly developed on a cross border basis, involving a range of academic, industry, public sector and social enterprise partners from across the three jurisdictions. A number of cross border meetings and workshops were held to develop the themes of the WPs, the PhD titles and the overall management and governance structures of the project.

The rationale for the inclusion of partners from outside the eligible area is to capitalise on the expertise of these two partners:

• STRATH, the UK’s Wind Energy Centre for Doctoral Training; and
• Sunamp, the only UK company with a deployable phase change material store for heat storage.</td></tr>
<tr><td>Joint Implementation</td><td>The project is being implemented on a cross border basis through:

1. A Joint Virtual Research Graduate School so that the 17 PhD students and their supervisors can:

a. Understand the wider goals and implications of SPIRE 2;
b. Share knowledge, expertise, scope future joint concepts and built working relationships;
c. Benefit from training modules in transferrable skills e.g. Ulster’s Epigium and specialist energy storage knowledge developed within the project;
d. Meet on a regular basis to engender the above concepts.

2. A Master degree programme with a series of modules detailing energy storage aspects. These modules can be taken individually as Continuing Professional Development or as a complete course via either Distance Learning or face-to-face options to provide education routes for graduates or knowledge upgrading for those in the industry wishing to focus on a particular aspect.
3. A jointly agreed technology transfer approach which broadly defines the process of transferring scientific and/or creative findings from one organisation to another for the purpose of further development and commercialisation, and ultimately, benefits the general public.

Each of the partners is contributing to the overall joint implementation of the project and its governance through participation in the management committee, advisory board or industry group. These groups have been developed to be cross-border in nature.

The project partners note that joint implementation for infrastructure alignment is necessary on a cross border basis through interconnector operations. They note that WP 2 will seek to address this.</td></tr>
<tr><td>Joint Staffing</td><td>The project is being jointly staffed, with the following specific research projects noted:

<table><tr><td>Northern Ireland and Ireland</td><td>• UU and DkIT in advanced heat pumps for heat recovery and upgrading from flow batteries bring practical sizing and integration skills of both skillsets together to capture and upgrade significant waste heat supplies from battery sets.
• UU, DkIT, Climote, QUB in control system development for the integration of distributed energy storage and the electrification of heat, thermal storage, Photovoltaics or other local variable renewable resources and the electricity system operators’ needs.</td></tr></table></td></tr>
</table>

		• UU, DkIT, AFC, PayPal in addressing energy storage integration for industrial complexes bringing together expertise in energy management and energy storage integration. • UU, DkIT, B9 and CCandGBG for community energy storage, linking skills in electricity markets, energy networks and site scale energy storage. • UU, QUB, UFU and DkIT will jointly assess farm-based energy storage typically connected single variable renewable energy resources such as wind that can struggle to get an electricity network export connection, bringing together skills of energy use, tariff management, electricity markets, network constraints to overcome this barrier.
	Scotland and Ireland	• STRATH and DkIT will address the challenges of offshore variable renewable energy system lifetime assessments through the integration of results from a range of leading test facilities and modelling capabilities.
	Scotland and Northern Ireland	• STRATH, QUB and UU in linking market models, electricity network models, lifetime performance models and meteorological models to grasps aspects of whole life operation and integration challenges of energy storage into existing electricity networks.
	Scotland, Ireland and Northern Ireland	• Domestic energy systems will bring together Energia, Sunamp, Arbarr, CES, QUB and UU in addressing the optimum integration path of renewable energy, energy storage, electrification of heat and electric vehicles. • SSE, ARBARR, QUB, STRATH and UU will address the integration of energy storage to existing onshore wind farms, accounting for their lifetime performance degradation, the loss of curtailment subsidies and new market structures, electricity network constraints and storage types.
Joint Finance	The project has been developed using **joint finance, with t**he split of budgets across jurisdictions reflecting the cross-border nature of this project.	

6.9 Impact on Business and Industry

This section considers the impact of the Renewable Engine project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

Notwithstanding this, anecdotal feedback from the Project Partners suggests that the project has served to (at least in part):

- Increase businesses' knowledge and understanding of the benefits of working collaboratively with academic institutions which may result in the development of longer-term working relationships;
- Linked to the previous point, the Project Partners note that businesses have developed a greater understanding of the respective research strengths and capabilities that exists within the academic institutions;
- Increase academia's understanding of the needs of industry; and
- Support businesses to take forward commercially focused R&D which may not have been undertaken due to their capacity and capability.

6.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the SPIRE 2 project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

6.10.1 EU2020 Objectives

The SPIRE 2 project continues to offer the potential to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth. Furthermore, the project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

6.10.2 *The Atlantic Strategy*

The SPIRE 2 project does not offer the potential to directly contribute to the aims and objectives of the Atlantic Strategy.

6.10.3 *The Horizontal Principals*

The SPIRE 2 project partners consider that the project will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

<table>
<tr><td>Sustainable development</td><td>
The project partners note that the SPIRE 2 project has sustainability at its core, as its central aim is to use mass energy storage (MES) to accelerate the transition to sustainable, clean energy. They suggest that effective electrical and heat energy storage will play a critical role in moving to a world powered by low-carbon sustainable energy system, with the SPIRE 2 aiming to prove that it is possible to provide a reliable, cost-effective and sustainable energy supply using mass-energy storage coupled with intermittent renewables.
They further note that the following indicators also reflect the potential impact of SPIRE 2:
<table>
<tr><td>Economic Development</td><td>Manufacturers (Glen Dimplex (NI) and Sunamp (Sco), Arbarr, (NI), Climote, Ireland) are included. Energy storage will serve to reduce demand peaks and therefore infrastructure challenges.</td></tr>
<tr><td>Education and Information</td><td> Post-Graduate Masters degree level modules are being used for Continuing Professional Development. The Masters in Energy Storage will promote the sustainability aspects of storage. This course has been designed to meet the energy storage sectors skills gap; educating passionate graduates from a range of academic and professional backgrounds, and giving them the skills and knowledge to make real change. Annual open workshops will disseminate and inform stakeholders. Traditional and social media outlets will inform of project updates and announce the release of position “white papers”. Courses and supporting materials will be provided to schools. </td></tr>
<tr><td>Innovation and Job Creation</td><td> UK energy storage businesses will contribute £6bn to £34bn to GDP by 2050. Local employment is emerging e.g. Gaelectric is receiving €14 million in funding from the EU to develop an energy storage project in NI. Innovation is integrating new energy storage technologies into emerging and new market structures thus integrating policymakers, market operators and developers to meet strategic energy and environment targets. Social enterprises and rural business e.g. Ulster Farmers Union are anticipated to benefit from the deployment of energy storage as subsidies for onshore wind power curtailment have been removed. It is envisaged that value for money will be assured through the project's 10 technology disclosures. </td></tr>
<tr><td>Economic Benefits</td><td> NI has world-class academic teams in the area of energy storage. These solutions will pave the way for a demonstration of more complex systems (e.g. offshore marine). Using air quality data, energy storage can replace more polluting energy services in the areas of poor air quality. There is a need to develop social intelligence on how the public will encounter energy storage at different scales and locations. </td></tr>
<tr><td>Investment for Sustainability</td><td>SPIRE 2 has been in communication with relevant government departments to address match funding. SPIRE 2 will employ a dedicated technology translator to engage with future funding opportunities.</td></tr>
<tr><td>Sustainable Communities</td><td>The inclusion of two community demonstrators will provide guidelines for future deployment.</td></tr>
<tr><td>Energy and Climate Change</td><td>SPIRE 2 will promote renewable energy, energy efficiency, cut energy consumption, reduce the use of fossil fuels and reduce CO2 emissions through the use of energy storage. Transport applications will benefit from battery development.</td></tr>
<tr><td>Natural Resources</td><td>Targets to use less oil and gas, reduce CO2 emissions and reduce dependence on imports of fossil fuels requires renewable energy which requires the use of energy storage to manage variability.</td></tr>
</table>
</td></tr>
<tr><td>Equal opportunities and</td><td>The project partners note that equal opportunities are embedded within each partner and have been applied to each of the organisations that recruited new staff through the project</td></tr>
</table>

non-discrimination	i.e. Ulster, QUB (both NI), Strathclyde (Scotland) and DkIT (Ireland). For example, Ulster University has an Equality Scheme 2012-2017 which sets out the University's commitment to and proposals for fulfilling statutory obligations in relation to Section 75 and Schedule 9 of the NI Act (1998). The University will promote equality of opportunity, taking account of all Section 75 groups and in addition, promotes good relations between persons of different religious belief, political opinion or racial group. The University has a system in place for accessing compliance with Section 75 duties, has arrangements for screening and carries out Equality Impact Assessments when required. Also, consultation, monitoring, the publication of assessments and monitoring, as well as training form part of the University's Equality Strategy. An equality scheme action plan accompanies the scheme. The application of appropriate equal opportunities policies across the project partners is understood to have been monitored by the Programme Manager.
Equality between men and women	The project partners state that gender equality issues were not treated any differently from any other aspect of equality of opportunity and gender equality policies, implementation and monitoring is addressed as described above for all other equality issues. At the outset of the project, each of the partners was informed of their requirement to adhere to statutory Equal Opportunities Policies including those that relate to gender equality. It is further noted that in order to address the underrepresentation of woman in science, Ulster has received a bronze award in the Athena Swan Charter in 2014. This Charter recognises and celebrates good employment practice for women working in science, technology, engineering and maths (STEM) in higher education and research. The Bronze Award submission includes a three-year Action Plan aimed at supporting and developing the careers of women in Science, Technology, Engineering and Mathematics at Ulster. Ulster University, as lead partner, has advised that it has sought to ensure that the principles of the Athena Swan Charter have been promoted across the partnership, with it noted that QUB is a Silver Award Holder and has seen encouraging increases over the last few years in female staff in more senior roles, whilst Strathclyde University currently holds a Bronze institutional award with 7 departments currently holding awards.

6.10.4 Contribution to Other Strategies

The SPIRE 2 project partners suggest that the project will support a number of local and regional strategies and initiatives across the programme area, including the following:

UK Research and Innovation/ Impact Strategies	The Project Partners suggest that SPIRE 2 aligns with the objectives of UK Research and Innovation (UKRI), which was established to deliver: • A greater focus and capacity to deliver on cross-cutting issues that are outside the core remits of the current funding bodies, such as multi- and inter-disciplinary research, enabling the system to respond rapidly and effectively to current and future challenges; • Improved collaboration between the research base and the commercialisation of discoveries in the business community, ensuring that research outcomes can be fully exploited for the benefit of the UK; and • Improved quality of evidence on the UK's research and innovation landscape through the pooling of multiple datasets and information sources, underpinning effective funding decisions. The project partners note that SPIRE 2 will particularly focus on delivering cross-cutting activities that integrate policies, market structures and technologies. Furthermore, SPIRE 2 through its energy supply chain structure will actively pursue improved collaboration between the research base and the commercialisation of discoveries in the business community through both the partnership and interaction with the Advisory Board.

Northern Ireland	In NI, The NI Executive endorsed DfE's Strategic Energy Framework (SEF) in 2012 which outlined the Executive's target of 40% renewable electricity consumption by 2020 in line with that of Ireland. SEF acknowledges the role that energy storage may play in the future NI energy mix and is supportive of storage where it may contribute to lower costs for consumers and the de-carbonisation agenda. The current draft Northern Ireland Programme (2016-2020) for Government emphasises a secure energy supply. The project partners note that the draft Programme for Government states that energy-related CO2 emissions must be cut in keeping with UK targets. SPIRE 2 promotes the integration of clean yet variable renewable energy through the use of energy storage. The PfG recognises that businesses and the workforce remain the key drivers of economic growth and a key outcome is about creating the conditions which support a deep and diverse export base helping to deliver increased employment and wealth. The key drivers of this outcome include innovation, research and development (R&D) and improving the skills and employability of those in, and those wishing to join, the workforce so that people can progress up the skills ladder, supporting higher levels of productivity. The project partners consider that SPIRE 2 contributes to this agenda with its business-focused research, innovation in novel technology development and skills training through its education programmes.
Ireland	Ireland has legally binding targets for renewable energy which must be met by 2020. Ireland's target for energy from renewable sources in gross final energy consumption is 16% by 2020. The National Renewable Energy Action Plan (NREAP) sets out the 40% 2020 interim targets for renewable electricity to be achieved by Ireland in order to meet its obligations under the Renewable Energy Directive. Innovation 2020 is Ireland's five-year strategy on research and development, science and technology. Innovation 2020 sets out the roadmap for continuing progress towards the goal of making Ireland a Global Innovation Leader, driving a strong sustainable economy and a better society. This is formed along six broad enterprise themes, as illustrated below.  According to the Project Partners, SPIRE 2 addresses the energy theme through the development and deployment of energy storage. It also addresses the themes of Manufacturing and Materials and Services and Business Processes in the development of strong links between all stakeholders in energy storage ranging from policymakers, energy suppliers, technology developers and energy users. SPIRE 2 is anticipated to enhance the "Testbed Ireland" concept in that it will demonstrate enhanced distributed mass energy storage (partially devised through "Horizon Scanning" with the Commercial Manager) operating with effective market structures enhancing the "Commercialisation of Research" and its strong partnership demonstrating "Collaboration for Innovation". The project partners further consider that SPIRE 2 demonstrates excellence in the higher education sector through concentrating expertise and achieving critical mass to provide optimal teaching, learning and research and improving the quality of postgraduate researcher education through excellent supervisor capacities and supporting relevant post-graduate courses that both broaden and deepen PhD experiences. They suggest that SPIRE 2 concentrates and opens access to quality

	Research Infrastructure and through cooperation enhances Research Excellence (measured by the UK Research Excellence Framework for example).
Scotland Strategies	The Scotland Plan for Government states that manufacturing accounts for over half of Scotland's international exports. The project partners consider that SPIRE 2 addresses manufacturing and its related research through improvements in wind and marine turbine materials and their relationship to system performance, network and storage capacity needs and ultimately related infrastructure developments. The Plan for Government also states that it will continue to support the world-class research that exists in our universities and boost collaboration between academia and business, thereby maximising benefits for society and the economy. The project partners suggest that SPIRE 2 will contribute to this with the participation of a leading Scottish University and Business. It addition, the partners note that Scotland's Economic Strategy 2015 stated that Scotland has strengths in a diverse range of sectors including Food and Drink, Financial and Business Services, Life Sciences, Energy, Tourism and Creative Industries and it will continue its focus on these key sectors. SPIRE 2 focuses on energy. Scotland's also has an energy policy ("Gone Green") of achieving 100% renewable electricity by 2020 (mostly from Wind). SPIRE 2 is aiming to develop energy storage technologies through appropriate variable renewable energy integration.

6.11 Barriers to Cross-Border Cooperation

According to the SPIRE 2 project partners, they have encountered (at July 2019) no barriers to cross-border cooperation that the priority axis is not addressing.

6.12 Exit Strategy

The SPIRE 2 project partners suggest that as a result of Ireland, NI and Scotland having among the most ambitious targets anywhere in the world for the integration of VRE, the challenges being faced in the eligible region are being watched with interest in countries which will face the same challenges in coming years and decades. They state that the central focus of SPIRE 2 i.e. mass (or wide-scale) energy storage, is seen by many industry analysts as the key to achieving a global transition to clean energy. Consequently, they believe that the project is ideally placed to exploit this surge of interest in energy storage, with the potential to position the eligible area as a global innovation centre for MES for years to come.

The project partners regard dissemination and exploitation of the results as being critical to the success of the SPIRE 2 project. As a result, SPIRE 2 has employed a Commercial Lead (CL) whose primary role is to secure the long-term impact of the project. Along with responsibility for all publicity and information activities, the CL is anticipated to co-ordinate the innovation actions of each institution, partner enterprise and the AB to bridge the gap between SPIRE 2 research results and exploitation. The Commercial Lead's role and responsibilities include:

i.	All Communications and publicity for the project and its partners (WP7)
ii.	Develop additional funding streams within international and national programmes (e.g. Innovate UK, innovation funding from partner Innovation Centres, Techstart, Lean Launchpad, Catalyst)
iii.	Identifying, contacting and establishing relationships with potential industrial partners on a global basis
iv.	Co-ordinating the innovation actions of partners
v.	Preparing a 'Legacy Business Plan' by month 24 to secure the long-term impact of the project
vi.	Where technology disclosures are made, the CL will assist with Disclosure Risk Analysis, Business Plan Development, Assistance for Patenting and Standardisation.

It is anticipated that the CL will work in close cooperation with the Innovation Offices of academic partners to identify technologies or services developed during the project which could be suitable for commercial development, and source investment funds for the commercial development of the project's research, to ensure the diffusion of knowledge into the private sector and to promote IP developed during the project.

Table 6.17: Suggested Commercialisation and Exploitation
According to the Spire 2 project partners, the structure of SPIRE 2 is strongly geared around future exploitation in that there are considerable early-stage analyses on the 'state of the art' and subsequent 'technology white papers' which allows SPIRE 2 to frame its necessary developments in terms of current and future Technology Readiness Levels (TRLs). The advances made in this project in terms of distributed energy storage technology development and variable renewable energy lifetime performance when integrated with new and emerging electricity market structures will provide both new technologies and new market services providing the region with a competitive advantage as markets and technologies are aligned. Planned developments in SPIRE 2 are that of an integrated cycle of new electricity market structures, their associated business models and energy storage technologies whose performance, siting and sizing account for the lifetime performance of the variable renewable energy system and electricity network they are serving. SPIRE 2 expects to generate at least eight intellectual property (IP) disclosures in: • Phase change material storage • Thermochemical material storage • Compact battery storage • New battery materials usage • Novel heat pump design • Novel materials for wind turbine blades • New biofouling preventative measures • Grid customer data solutions. Background IP is owned by each partner or stakeholder participant and new foreground IP developed in the project is shared among the developers. SPIRE 2 will utilise the expertise of the Innovation/Commercialisation Offices of each partner institution, the related activities of partner enterprises and the wider stakeholder engagement of its Advisory Board members to bridge the gap between SPIRE 2 research results and commercial exploitation and technology transfer. A parallel activity within the project will develop a 'Value Proposition' for early and ongoing identification of profitable areas through technology suppliers, distribution system operators, transmission system operators (TSO), distribution system operators (DSO), central producers and O&M (operation and maintenance) providers and various stakeholders. The research findings will be disseminated through peer-reviewed journal literature (e.g. Applied Thermal Engineering, Energy Policy, Journal of Heat and Mass Transfer and the International Journal of Refrigeration), through presentations at conferences and through media/social media and through the project website.

In order to maintain the project without European funding, the CL will seek to identify further research funding opportunities (in the UK and beyond). This will include a particular focus on non-EU sources of funding to mitigate the uncertainty surrounding Brexit and the possibility of INTERREG funding being curtailed.

In addition to the work of the CL, it is envisaged that the project's output will be incorporated into teaching materials for relevant courses at partner institutions (Ulster, DkIT, STRATH, QUB). In this way, project results will be disseminated to and through undergraduate and postgraduate students.

7. ECME - EASTERN CORRIDOR MEDICAL ENGINEERING CENTRE

7.1 Introduction

This section of the report considers the ECME (Eastern Corridor Medical Engineering Centre) project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry-relevant research and innovation capacity across the region.

7.2 Project Overview

7.2.1 Background

Globally, people are living longer and striving to lead independent, happy, and healthy lives. As such, healthcare for ageing populations is a global issue that all countries face, with all three jurisdictions' health strategies recognising that this population presents the greatest challenge to providing sustainable and affordable healthcare. Projections see the world's aged population increasing from 287 million in 2013 to 417m in 2050[74], which will bring with it a higher level of age-related illnesses and injuries. As a consequence, public health care expenditure in the EU27 is projected to increase from 7.1% of GDP in 2010 to 8.4% in 2060.

The Eastern Corridor Medical Engineering Centre (ECME) project focuses on cardiology as this is closely aligned to ageing populations; physiological changes in the ageing heart and blood vessels including the heart becoming less efficient, less responsive to stimulation and less able to increase strength during contractions. These are all areas that the project aims to address via monitoring; diagnostics and computational aids.

The three jurisdictions top the International League table for high percentages of cardiac disease within their respective populations, with it being the most common cause of death in Ireland, currently accounting for one-third of all deaths and 20% of premature deaths. In Northern Ireland, cardiovascular disease remains one of the most significant causes of death. In 2011, 28% of all deaths were caused by cardiovascular disease (CVD), almost 4,000 people. This figure was almost as high as deaths caused by cancer (29%). Costs for inpatient episodes and day-case attendances in acute hospital settings in Northern Ireland show the total expenditure on CVD in Northern Ireland in 2013/14 to be £393 million. Data for Scotland indicates that in 2011/12 close to £800 million was spent on treating CVD, equating to more than £150 per person in the country. More than twice as many people in NI have heart disease as in ROI – 8.8% vis-à-vis 4.1% and people from low socio-economic backgrounds are more likely to suffer.

The management of heart disease and related diseases have benefitted from behavioural shifts e.g. reduced number of tobacco smokers and increased societal digital literacy; as well as from technologically advanced interventions such as stenting, pacemakers and implantable defibrillators. Whilst these advances have led to improved short-term case fatality rates, they result in people living longer with heart failure; which has higher resource implications.

Research in Scotland[75] highlights the rising incidence in heart failure, and the impact that this has on GPs visits and hospitalisation, noting that the expectation is that between 2000 and 2020 there is a projected increase in heart failure prevalence by 31% in men and 17% in women; leading to an increased call on GP resources of 40% and 16% respectively; and an increase in hospital admissions of 34% and 12% respectively. Given that the costs for in-patient episodes and day-case attendances in acute hospital settings for cardiovascular diseases (CVD) in Northern Ireland were £393 million in 2013/14; £800m in Scotland and €925m in Ireland, it is clear that the magnitude of the rising costs is significant and a project that enables this to be more efficiently managed has the potential to represent value for money.

[74] WHO http://www.who.int/ageing/events/world-report-2015-launch/en/
[75] Heart failure and the aging population: an increasing burden in the 21st century, Heart 2003

Remote patient monitoring, which is the focus of ECME's work packages, has the ability to reduce costs, improve quality of life and improve outcomes of patients with chronic diseases. A report, "WSN for Healthcare" and another by Jupiter estimates that wireless sensor networks can reduce annual health care costs, by up to $36 billion worldwide by 2018 and although this is well less than 1% of total $7trillion global spend, it offers many opportunities. Much of the savings are derived by reducing hospitalisations and extending independent living for seniors.

7.2.2 *The ECME Centre Project*

The eligible region has recognised business export excellence within the target market of remote patient diagnostics; and has research excellence in the key disciplines of medical engineering, data analytics and diagnostic systems. By specifically taking all the various specialisms under one project, it is envisaged that there will be an enhanced critical mass of expertise that should lead to industry innovation, informed by research and development.

To this end, ECME represents a collaboration between the two main centres within the Island of Ireland in Intelligent Sensor Technology, namely:

- Ulster University's (UU) Nanotechnology and Integrated Bio-Engineering Centre (NIBEC), in conjunction with UU's Computer Science Research Institute (CSRI); and
- Dublin City University's (DCU) Biomedical Diagnostics Institute (BDI), in conjunction with:

  - Dundalk Institute of Technology (DkIT); and
  - University College Dublin's (UCD) Connected Health programme, incorporating the Applied Research for Connected Health Centre (ARCH) and the Insight Centre for Data Analytics (INSIGHT, Prof Brian Caulfield).

The project also incorporates a new partnership with the University of the Highlands and Islands' (UHI) Department of Diabetes and Cardiovascular Science to complement the work with a strong underpinning of cardiovascular research. The main clinical partner is the Cardiac Research Centre at NI's Southern Trust (ST, Craigavon).

This newly formed 'ECME Alliance' intends to work closely with a range of industrial and clinical partners as a means of translating collaborative science into clinical and market-led innovative products and systems for enhanced healthcare applications.

The ECME project involves a number of key activities, that are captured within seven work packages, with the research and innovation activities grouped into five separate work packages based around an industry-informed challenge. The project also includes a communication/dissemination strategy that seeks to optimise the potential economic benefits of the envisaged newly developed know-how.

The Project's aims are:

- To implement a cross border centre of critical mass and excellence that will enable the partner research institutes to improve their credibility and standing in the international community through jointly published cutting-edge research in the field of remote patient monitoring;
- To provide a new business integration mechanism that demonstrates the economic benefit of RI-led approaches to industry-identified issues, with commercialisation foreseen through spin-outs and new product development in industry partner businesses;
- To provide a big data structure and database that will enable future joint working amongst partners to enrich the validity of health and life science solutions developed;
- To develop leaders of the future through the industry and innovation enriched and informed PhD studentships;
- To set-up a tri-jurisdiction research collaboration in cardiac sensors, diagnostics and data analytics. We aim to develop this into an internationally leading doctoral training and innovation centre, with critical mass that allows global recognition, high-quality leadership development and excellent Industry interactions.

The partnership had previously been highly successful at influencing EU and global impact within their respective areas. It is anticipated that the ECME project will provide the partnership with the impetus and funding to work collectively to make a step change to where industry and academia are placed in the globally competitive remote patient monitoring market. The various PhD projects and RA innovation projects that comprise the ECME Centre projects were informed through the partnership's experience and consultation with industry leaders.

According to the project partners, the project builds on existing work in single jurisdictions and has the potential to create a research and innovation powerhouse, that will not only produce world-renowned research but will also stimulate the private sector to formulate solutions to key industry challenges.

Whilst the partners already have strong ties with industry, it is anticipated that the programme will address new and deeper relationships. The project partners advise that the project has been co-designed with industry to address market issues and trends/opportunities. The industry partners are core to the project and are anticipated to be well placed to benefit from Commercial Processes Training (Business models, interaction with Universities and Hospitals, clinical trials, adoption and procurement), IP Development, Training (Regulatory, Prototyping and Research Skills) and Process Development utilising best practice techniques.

A number of companies will be encouraged to avail of the network; PhD exchange; researcher in residence and knowledge transfer/innovation schemes. In return, it is envisaged that companies will benefit from new training; new knowledge/skills and tools; access to key academic experts; further funding opportunities. The programme is designed to deliver 5 new major **technology platform work packages** and industry will get an insight as to how to integrate these with their innovation roadmaps.

From the researchers' perspective, a key focus will be placed upon the option of taking forward a spin-out from the university. To this end, the project partners have mandated that all researchers (both PhD and RA level) undertake a tailored course emerging in the area referred to as the Lean Start Innovation Programme.

The project's fundamental science base will be developed via a range of PhD programmes aligned to 5 research clusters (RCs), RC funding and focused activities in topics such as nanomaterials, microfluidics, computational algorithms, data analysis, cell-surface interactions and electrode interfaces and impedance spectroscopy. It is anticipated that these factors will underpin each project as well as sustain the programme's high levels of innovation.

ECME will undertake R&D in clinically **important product platforms** and prototype devices that involve at their core the formulation, fabrication, characterisation and integration of key custom-designed devices. Importantly here, the engineering aspects will be combined with computer modelling, hardware and software to derive products that have both sensing and therapeutic functionality. The project partners' existing IP portfolio and proven expertise in the technologies of computational algorithms; data analytics; micro-fabrication and nanotechnology, provide a clear platform on which they can build an internationally leading Centre. The collaborative R&D outcomes that are anticipated to result from these activities will be targeted at improving healthcare via the delivery of significant advances in sensor-based diagnostic technologies. This core area is directly linked to real clinical challenges and thus to commercial opportunity.

The overall project will continuously take cardiac specialist clinical direction and advice from 3 Southern Trust cardiologists, along with NHS Scotland and ROI HSE input. A range of PhD projects will be managed by the clinicians and PhD students will be continuously introduced into the clinical environment with some placements possible in their final years.

The five ECME research and innovation work packages cover various aspects of remote patient monitoring within cardiology that have been informed and shaped by industry.

It is anticipated that the project will involve 24 PhDs delivered over three and four year periods with varying technology ready levels, which will feed into and shape five demonstrator platforms (developed and co-ordinated by three RAs, a Business Integration Manager and industry) that specifically address five key industry issues.

It is anticipated that the PhD students will acquire transferable skills such as research management and communication skills that will shape their training and career development to best position them for their future careers. The programmes feature three network-wide transferrable skills modules (Inter-sectoral Communication (including IP management); Innovation in an emerging market; Working with patient populations: ethics, access and clinician engagement.

Other transferable skills such as presentation skills, research writing and more will be delivered at a local level. It is also envisaged that the PhD students will learn entrepreneurial skills, helping them to think creatively and explore career paths beyond an academic setting. Dissemination events such as the "Health hack" will encourage the development of an entrepreneurial mindset and many of the research leads who have either spun-out companies from their research; or have multiple patents to their names. Inter-sectoral and interdisciplinary mobility means that the ESRs will receive wider experience than that traditionally offered to researchers by introducing them to areas beyond their fields and beyond the academic setting.

The programme will adhere to the 7 Principles for Innovative Doctoral Training:

1. Research Excellence;
2. Attractive Institutional Environment;
3. Interdisciplinary research options;
4. Exposure to industry and other relevant employment sectors;
5. International networking;
6. Transferable skills training;
7. Quality assurance.

In addition, a Lean Start-up Programme will be introduced in a 3-day course that will bring all PhD students and PDRAs together in Year Two in order to focus on our commercialisation strategy and training[76].

An overview of each of the 5 technology platform work packages is provided in the following sub-sections, together with an overview of their associated PhD projects.

[76] Lean start-up is a method for developing businesses and products first proposed in 2008 by Eric Ries. NB this programme is funded by Invest NI and is a core offering of UU, as such no direct ECME costs are attributed to same. The key is that the principles of lean start will be encouraged within the various work packages.

7.2.3 Cardiac Big Data R&I Work Package

Table 7.1: R&I Work Package 1 - Cardiac Big Data R&I	
Overview	**Key Anticipated Deliverables**
There is a lack of critical mass in each jurisdiction to develop big data sets in the area of cardiology [in this instance, big data is patient information that feeds the development and use of algorithms to inform ICT-based solutions]. For example, no all-Ireland database exists in areas such as cardiovascular or respiratory disease to allow for the development of early detection systems. ROI has patient data held for circa 20,000 cardio patients; whereas NI only holds data for circa 2,000 cardiac patients, which does not provide a suitably scaled database from which meaningful research may be undertaken. Industry partners note the need for large data sets of multi-demographic cardio patient data and the key drivers are the need to address the regions critical need for faster, higher quality, lower cost cardiac care. Existing commercial interest is high with all industry partners, with a strong focus on technology platforms addressing self-management or faster decision making in cardiology. The key industry challenge is that there is a lack of suitably constructed and cleansed large data sets of multi-demographic cardio patient data from which solutions can be developed (smart algorithms; justification of a biomarker; economic analysis; developing a rational or protocol etc.) to provide timelier interventions of a higher quality and lower cost. The combination of the various cross border cardio-databases held between the three jurisdictions will provide a more robust dataset that will enable enriched research and underlying integrity to solutions developed. By working with patient data, regardless of the borders, there is an opportunity to benefit all participant jurisdictions. WP1 will address this opportunity and will represent an enabler for all other work packages. This WP is expected to have high commercialisation potential – the data models and cloud-based platforms will be key to the development of intelligent systems. Clinical engagement and challenging research projects will be enhanced when such a dataset is compiled with applications focused towards socio-economic outputs; algorithm alarming; trend analysis and statistical analysis.	1. Four PhD programmes will be undertaken; 2. A central database will be established by the PDRA to host structured cardiac data sets in order to allow algorithm development; trend analysis and new analytical methodologies to be developed. This will form the basis of a static and cloud-based platform solution. 3. Preparation of a "cloud-based platform demonstrator of cardiac based data storage and analysis tools": with an early-stage prototype platform by April 2018; a second stage platform demonstrator by March 2019 and an optimised platform demonstrator by March 2020. This will be underpinned by the associated PhD outputs, academic staff expertise and experience and a percentage of time input from the on-site PDRA. 4. Two-month industry placement for each PhD student. 5. One to many engagements with the following six organisations through the RA and Business Integration Manager (BIM) to refine and market test the platform through dissemination workshops, training and mini-projects. Businesses that were identified by the Project Partnership to potentially receive support included: • Southern Trust • Randox • Heartsine • Intelesens • Kainos • First Derivatives 6. Grant award to one business to assist in the development of next stage designs emerging from the new platform (subject to IP agreement); 7. Clinical integration - In this project, the clinicians will help with addressing clinical issues associated with protocols, overall design, data assessment and overall clinical direction; 8. Publish five peer-reviewed publications and theses (one per PhD student) by December 2021; 9. Prepare 12 other peer-reviewed publications (by supervising staff and academia within the wider project staff) by December 2021.

Summary of Cardiac Big Data R&I PhD projects

Table 7.2: R&I Work Package 1 - Cardiac Big Data R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 3	Development of Multi-Parameter Models for Rapid Diagnosis and Treatment of Cardiovascular Disease	NIBEC	Whilst there has already been much innovation in the development of new methods for the detection and treatment of cardiovascular disease emerging technologies are providing the catalyst for further significant development. New and emerging methods in large scale data mining and data analytics are providing an unprecedented opportunity to facilitate the development and tuning of the next generation of clinical tools. This project will exploit large datasets of multimodal cardiovascular patient data to develop tools to support the rapid diagnosis of cardiovascular disease. The analysis will focus on the application of emerging techniques to composite datasets that consists of parameters that include vital signs, cardiac biomarkers and medical imagery. To date, automated cardiovascular diagnostic tools have largely focused on single disease modelling through individual parameter analysis (e.g. vital signs only). In this project, the opportunity/challenge will be to understand and exploit the relationships between data from a number of diverse biological sources and increase diagnostic yield across a number of cardiovascular disease types (e.g. arrhythmia and non-arrhythmia disease groups). If this challenge can be met the impact is likely to extend beyond more accurate diagnosis to development of improved long-term care. Specifically, it is believed that understanding of such rich data will allow the development of patient-specific models that will, in turn, facilitate the development of effective personalised and tailored treatment strategies.	3 years
PhD 6	Connecting Medical Devices to an IT network – Risk Management and Security	DkIT	Due to the growing need to provide care at home for the management of chronic diseases, medical devices are increasingly being designed to be placed onto an IT network. Placing a device onto a network can provide many advantages in terms of patient care but may also pose risks to the safety, effectiveness, and security of the medical device negating the potential benefits. Risk Management Standards, such as the IEC 80001-1 series, and regulations governing the storage and exchange of protected health information, such as the Health Insurance Portability and Accountability Act (HIPAA) have been and are being produced to address these issues. However, Healthcare Delivery Organisations (HDOs) and Medical Device Manufacturers (MDMs) struggle to implement the requirements of these standards and regulations. Aims 1. Investigate the current standards and regulations with which HDOs and MDMs need to comply when a placing a device onto an IT network to ensure the safety and effectiveness of medical devices on the network while protecting health information. 2. Develop an approach which can assist HDOs and MDMs in implementing the requirements of standards which address risk management and security concerns related to placing a device onto the network. Anticipated Impact This research work will focus on the development of an approach which can assist HDOs and MDMs in implementing the requirements of standards and regulations related to risk management. The approach will allow HDOs and MDMs to leverage the benefits of networked medical devices while ensuring that the risk of placing the device on the network is managed and that health information is protected in line with the relevant standards and regulations. Collaboration with the Regulated Software Research Centre (RSRC) in DkIT and other data analytic partners will be key. The RSRC has extensive experience in the development of a number of international standards to ensure the safety and security of medical devices. Industry Collaborators are yet to be confirmed.	4 years

Table 7.2: R&I Work Package 1 - Cardiac Big Data R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 7	The design and effectiveness of a technology-based system that uses multiple behaviour change techniques to deliver multiple health and wellbeing interventions	DkIT	Historically, behaviour change interventions have targeted one specific area of health and/or wellbeing, e.g. weight control. However, older adults typically have multiple co-morbidities and therefore a holistic view of the person is necessary when delivering interventions. This may necessitate delivery of multiple interventions targeting health and wellbeing management (e.g. take vital signs, track and manage medications, sleep hygiene), lifestyle choices (diet, physical activity, smoking cessation), as well as interventions targeted at encouraging technology usage. This project will explore how best to design technology-based systems that use multiple behaviour change techniques to deliver multiple health and wellbeing interventions, evaluating their effectiveness and impact for this population. Aims 1. Explore and evaluate design opportunities for implementing multiple behaviour change interventions in older people with heart conditions and co-morbidities. 2 Evaluate the impact of these techniques in practice over a 12-month study. 3 Investigate the impact of technology on supporting / inhibiting behaviour change via compiled datasets. Anticipated Impact / Link to RA Platform Enhance the data set by improving data information on areas where intervention has occurred.	4 years
PhD 17	In-silco personalized patient modelling for better outcomes and interventional procedure planning.	Southern Trust	Improvements in cardiovascular medicine over these past 20-30 years have seen a dramatic increase in the number of people living longer with chronic cardiovascular conditions. This has meant that cardiovascular research has continually refocused to adapt to cardiovascular conditions that become more prevalent when patients live longer with chronic conditions (e.g. AF, stork, heart failure). Treatment of chronic conditions has a fortuitous consequence that is currently not well exploited. Specifically, the patient undergoing long term treatment for chronic cardiac conditions have the potential to generate a rich source of personalised data specific to their own physiological profile. This has resulted in the definition of the “virtual physiological human” (VHP) concept. The VPH is based upon the collection of multi-parameter patient-specific data (vital signs, medication profiles etc.) that allow compiling in-silica patient modelling. In this program of research, the VPH approach will be exploited to promote better outcomes for chronic cardiovascular disease patients. Aim The aim of the project is to recruit chronic cardiovascular disease patients and build VPH models for each subject to allow better stratification of patient prognosis and treatment. The models will be based on a compilation of rich data recorded from a number of clinical sources and the home environment. This project will allow not only for data from different patient environments but could potentially include inter-regional data hosted/collected on different healthcare provider systems. This data will be mined to allow patient-specific models to be generated to allow better planning of treatment and interventions (e.g. pre-procedure simulation for interventional planning). Medical/Clinical Knowledge formalised in guidelines, standards and protocols and used to promote translation of basic science and integrative models into healthcare benefits. Technical/Engineering Knowledge formalized in guidelines, standards and protocols and used to promote data sharing and model development across clinical, patient and regional boundaries. Anticipated Impact This will have a strong impact on guidelines and FDA protocols.	3 years

7.2.4 *Smart Wearables founded in Connected Sensor R&I Work Package*

Table 7.3: R&I Work Package 2 - Smart Wearables founded in Connected Sensor R&I	
Overview	**Key Anticipated Deliverables**
By 2020, according to the World Economic Forum, more than 5 billion people and 30 billion "things" will be connected to the Internet[77]. The success of these devices is due to the ever-present consumer interest in exercise monitoring and performance measurement coupled with the availability of fit for purpose, cost-effective and seamlessly integrated technology. A key driver has also been the proliferation of smartphone technology as many of the available devices serve as peripherals extending the functionality of the smartphone. Technical impediments – Whilst commercially available wearable technology solutions appear to perform reliably, their measurements are simply not fit for purpose in clinical decision making. Specifically, many systems use sophisticated algorithms to augment, and in some cases artificially supplement, poor quality and noisy data that is harvested from sensors. This is not acceptable in medical device grade systems, an issue that has been raised by the FDA. A further technical issue is that whilst the development of smartphone technology has brought about significant advances in user experience, and, this user experience has helped promote lifestyle and fitness monitoring systems the development of the electrodes and the sensors on which these systems rely has been much less accelerated. There is still much to be gained in healthcare sensor development. Current healthcare systems are not well facilitated to embrace the current generation of wearable technologies. In most cases, these systems require not just a change in equipment/device but also a change in clinical practice. Not only do these systems provide more data in potentially a different format the complexities of, for example, integrating a patient's own smartphone or data plan into the service provision are not well addressed. The project partners have experience of formatting data to APIs; cloud services (Amazon Web Services) and ECRs systems. Regulatory Issues - Closely related to the above, the uptake of wearable technology in healthcare applications is subject to regulatory consideration. Wearable technology provides much more capacity for individual patients to record, store and manage their own healthcare data. This makes regulation of the related devices important. In particular, over this past 4-5 years, medical device regulators have faced challenging decisions on how to regulate wearable technology for use in clinical practice. This, in turn, brings challenges for those wishing to market this technology for such purposes. The overall aim of this work package is to develop **clinically competent wearable technology** systems that are cost-effective and can be seamlessly integrated into current practice. This aim will be met through the following objectives: Identification of the current state of the art in wearable technology is compatible with the clinical need. Development of advanced healthcare sensors which offer high integrity data collection at disposable unit cost. Development of embedded architectures that will meet regulatory compliance as the medical internet of things devices. Delivery of medical internet of things compliant devices which are highly integrable to current healthcare IT systems providing a seamless user experience for all users.	1. Five PhD programmes will be undertaken; 2. A demonstrator platform will be developed which will be underpinned by the associated PhD outputs, academic staff expertise and experience and a percentage of time input from the on-site PDRA - This work package will see the development of a state-of-the-art platform to allow the development of commercial medical device grade wearable technology. The work package will benefit from a specialist team that brings expertise in three key areas: Medical device and sensor development; Clinical practitioners; Medical device regulation. The work will base developments on the Internet of Things (IoT) model. When specific to medical applications this is often referred to as the Medical Internet of Things, the Internet of Medical Things or the Internet of Things – MD. Anticipated to have an early-stage prototype platform by April 2018; a second stage platform demonstrator by March 2019 and an optimised platform demonstrator by March 2020. 3. Two-month industry placement for each PhD student. 4. One to many engagements with the following 4 organisations through the RA and BIM to refine and market test the platform through dissemination workshops, training and mini-projects. Businesses/organisations that were identified by the Project Partnership to potentially receive support included: • Intelesens; • Lifescan; • Heartsine; • Kainos; and • Southern Trust. 5. Grant award to one business to assist in the development of next stage designs emerging from the new platform (subject to IP agreement); 6. Clinicians at ST will inform design; UX design; construct suitable clinical protocols, perform technical evaluation studies and help publish outputs. 7. To publish five peer-reviewed publications and theses (one per PhD student) by December 2021; 8. To prepare 12 other peer-reviewed publications (by supervising staff and academia within the wider project staff) by December 2021

[77]http://reports.weforum.org/digital-transformation-of-industries/wpcontent/blogs.dir/94/mp/files/pages/files/digital-enterprise-narrative-final-january-2016.pdf

Summary of Smart Wearables founded in Connected Sensor R&I PhD projects

Table 7.4: R&I Work Package 2 - Smart Wearables founded in Connected Sensor R&I PhD Programmes

PhD Ref	Title	Based in	Description	Duration
PhD 2	Remote Telemetry of Oxidative Stress Processes in the Management of Stroke: Acquisition and Processing of Metabolomic Data	UU	Reactive oxygen species (ROS) and oxidative stress are major contributors to the pathogenesis of cerebrovascular disease and cardiovascular deterioration and there has been a substantial number of studies aimed at elucidating the role of the various components. Under a variety of stroke pathological states, ROS-mediated oxidative damage is dramatically accelerated and leads to irreversible brain damage, cerebral dysfunction, cognitive decline, and death. An overwhelming body of scientific evidence now points to ROS-mediated oxidative damage as a key pathogenic pathway involved in the earliest stages of many neurodegenerative diseases. Technology and data processing methods that can facilitate the quantitative detection and hence monitoring of not only ROS species but all the key players in the biochemical milieu. It can be envisaged that through the provision of such technologies at the point of care (POC), the acquisition of real-time data relating to the dynamics of such molecules would provide the clinical research community with invaluable information that would allow elucidation of the biochemical pathways involved in redox regulation occurring before and immediately after the onset of cerebrovascular or large artery atherothrombotic stroke. Aim The core aim of the project is to lay the foundations for a remote diagnostics and telemetry patch technology that is capable of providing unassisted periodic monitoring of small molecule metabolites for use in the assessment and subsequent clinical management of stroke. The project seeks to enable the realisation of a point of care technology platform that could induce a transformative change in the diagnostic toolkits of researchers, front line clinicians and community support workers. Current assay systems detect only a single (or at most a limited number) of biologically relevant species, require complex, time-consuming, labour-intensive analytical processing, and are temporally compromised with respect to the short half-lives of most biologically relevant ROS species. This last point is especially important and frequently overlooked. By the time analytical measurements are initiated using conventional methods, significant loss of signal has accrued due to decomposition. The project would develop the foundations that enable the robust collation of real-time data relating to the dynamics of the main protagonists in the oxidative stress processes known to have a direct impact on the condition and subsequent complications. Anticipated Impact There are no commercially available technologies to provide the above and thus a transformative research program to develop an innovative nanotechnology-based toolkit for measuring ROS in biological systems is proposed. A label-free integrated sensor and simplified detection procedure will enable sequential analytical operation on a small, inexpensive chip. The foundations for the latter have already been laid. A micropatch system whose 3D architecture allows for large scale multi-parametric detection was developed by the applicant through prior EPSRC funding (GR/S85351 and GR/S47984). This is equivalent to high throughput screening but on an inherently disposable system. The present challenge is, therefore, to develop the data analytics in regard to the concentration profiles recorded through electrochemical interrogation of the sensors.	3 years

Table 7.4: R&I Work Package 2 - Smart Wearables founded in Connected Sensor R&I PhD Programmes

PhD Ref	Title	Based in	Description	Duration
PhD 15	Development and Evaluation of mobile-based adaptive training programme for patients with cardiac conditions	DkIT	Physical rehabilitation and lifestyle management are critical components of programmes aimed at primary and secondary prevention of cardiac disease. A major challenge in implementing these strategies is the problem of ensuring good patient engagement and compliance with prescribed exercise programmes and nutrition plans. Evidence from the literature suggests that only tightly supervised intervention programmes have been successful and that self-directed management is not successful due to problems with engagement and adherence. The problem lies in expecting patients with a wide variety of life patterns and personality types to conform to standardized prescribed programmes that do not fit with their ever-changing context. The combination of evidence-based contextually relevant recommendation engines and personalised adaptive training programmes has the potential to address this problem. <u>Aims</u> 1 Develop and evaluate a personalised lifestyle recommendation application for cardiac patients. 2 Implement this recommender system in tandem with an adaptive training programme in cardiac patients and evaluate its capacity to affect a meaningful and ongoing change in health-related behaviours. <u>Anticipated Impact</u> Improve sensor technology for improved rehabilitation programmes.	4 years
PhD 16	Development and Evaluation of mobile-based monitoring programme for Congestive Heart Failure	UCD	Congestive Heart Failure is associated with repeated cycles of exacerbation and remission, leading to frequent unexpected admissions to hospital. Effective monitoring of CHF patients could lead to the implementation of early warning systems that can prevent exacerbations escalating to the point where hospital admission is required, resulting in better outcomes for patients and reduced healthcare costs. However, monitoring programmes to date have had limited success for a variety of reasons. In this work we will explore the potential for leveraging sensor streams from the patient's mobile phone, in concert with wearables such as the Intelesens ECG, to develop exacerbation prediction algorithms. <u>Aims</u> Co-design (with patients), implementation and user evaluation of mobile app for data capture, integration and visualisation, and associated monitoring protocol. Leverage dataset from app deployment in a patient cohort to develop exacerbation prediction algorithms. <u>Anticipated Impact</u> The effective solution to the problem of predicting exacerbations in CHF and reducing unnecessary hospital admissions	4 years
PhD 20	Cardiology wearables	UHI	Wearable devices for constant assessment of cardiac parameters is an attractive opportunity for Cardiologists, but the data available to support the benefits of such devices in terms of clinical outcome, healthcare system utilisation and economic healthcare system savings has not yet been comprehensively assessed. Such assessment is the critical next step to enable healthcare providers to make informed decisions as to the relative merits of wearable cardiovascular monitors as an integral part of healthcare systems. <u>Aims</u> To deploy wearable technology (Alivecor) with patients with coronary artery disease in the cross-border region and to collect the data generated from the technology. To interrogate the data in the context of outcomes for the patients as well as potential healthcare system savings and implementation barriers. <u>Anticipated Impact</u> Improve wearable knowledge and database, and gain industry interest.	3 years

Table 7.4: R&I Work Package 2 - Smart Wearables founded in Connected Sensor R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 18	Implantable devices meets medical internet of things	Southern Trust	A new generation of Internet-enabled medical devices has emerged that allow ultra-connectivity in the clinical setting. This level of connectivity has not yet extended to invasively implanted wearable devices. Whilst many implantable cardiovascular devices (e.g. pacemakers and implantable defibrillators) do have the capacity to wirelessly connect to external devices there has not yet emerged a model that allows these devices to serve as true IoT devices. This project will see the development of a modular approach to IoT connectivity for implantables. Whilst the majority of implantable development is sensor-driven, in that the capability of the embedded sensors are the limiting factor, the ultimate utility of these devices must be underpinned by clinically-led development. <u>Aims</u> Clinically led development of implantable devices compatible with IoT. <u>Anticipated Impact</u> Improve wearable knowledge and database, and gain industry interest	3 years

7.2.5 Rapid Homecare Point of Care R&I Work Package

Table 7.5: R&I Work Package 3 - Rapid Homecare Point of Care Diagnostics R&I

Overview	Key Anticipated Deliverables
In keeping with the fact that people with chronic heart disease are living longer, there is an obvious benefit to the public purse for these individuals to only visit hospital when absolutely necessary and in a timely fashion. Research shows that at-home telemonitoring has reduced the cost of healthcare by 20% in the case of diabetic management for example. In the development of the enhanced patient monitoring market, industry has identified a key weakness as being the lack of miniaturised high-quality diagnostics that are affordable and easily used in the home care setting by non-medical staff. Furthermore, industry leaders are seeking to always improve on the key parameters for marketing needs, of sensitivity (quality of data), specificity (only sensitive to what it is measuring), predictive ability and False Positive / False Negative systems (high ROC curves) of any point of care diagnostics. Also, a range of methodologies including optics (colourimetric, fluorescent, time-resolved fluorescence) to electrochemical or variations are all options that need clarity depending on the UX, need and cost. A platform will be optimised around these parameters with low cost, portability, meeting the regulatory standards and high UX being the key drivers. There is, therefore, a great need for higher quality diagnostics and the point of care in lower-cost miniaturised formats to address the future of home care monitoring; self-care and the needs of the developing world. Research which supports the development of rapid diagnostic tests that can be deployed to the community has a potentially high return as it can address long waiting times and delays to treatment or decision i.e. the key to TYC in all jurisdictions. Based on UU’s historical relationships with DCU through the very successful BEST Centre, testbed successes at DKIT and new relationships with UCD and UHI, the project partners are confident that this partnership can deliver a powerful platform to deliver the focus for next-generation point of care systems. Industry partners have indicated that the key trend and need is high sensitivity; high specificity; highly predictive; low FP/FN systems (high ROC curves). Portability, low cost, good UX and robustness are also key attributes. Existing commercial interest is very high; with the partner, regions specialising in diagnostics. The key challenges include the identification of the relevant novel biomarkers, DNA-based biosensors, development of robust tests that work in the community and can be used by non-professionals with minimal training, good UX or instruction.	1. Five PhD programmes will be undertaken; 2. A microfluidic platform for general testing, blood collection and filtering will be established and fabricated, which will be underpinned by the associated PhD outputs, academic staff expertise and experience and a percentage of time input from the on-site PDRA. Anticipated to have an early-stage prototype platform by April 2018; a second stage platform demonstrator by March 2019 and an optimised platform demonstrator by March 2020. 3. Two-month industry placement for each PhD student. 4. One to many engagements with the following seven organisations through the RA and BIM to refine and market test the platform through dissemination workshops, training and mini-projects. Businesses/organisations that were identified by the Project Partnership to potentially receive support included: • ST • JandJ / LifeScan • Abbott • Epona • Randox • SiSaf • First Derivatives 5. Grant award to one business to assist in the development of next stage designs emerging from the new platform (subject to IP agreement) 6. In the area of point of care, diagnostics clinicians are continuously informing the academics teams of the need for specific biomarkers in cardiology. These changes have protein-specific molecules become available, or NICE guidelines change or medication procedures are adjusted 7. To publish five peer-reviewed publications and theses (one per PhD student) by December 2021; 8. To prepare 11 other peer-reviewed publications (by supervising staff and academia within the wider project staff) by December 2021.

Summary of Rapid Homecare Point of Care Diagnostics PhD projects

Table 7.6: R&I Work Package 3 - Rapid Homecare Point of Care Diagnostics R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 1	The development of a new integrated rapid cardiac enzyme sensor for CPR analyses associated with portable defibrillators	NIBEC	Survival rates after cardio-respiratory arrest and CPR are low: In the hospital, the chance of surviving to discharge is 15-20%; out of the hospital, the chance of surviving is lower at 5-10%. There is a need to improve access to AED's and also deliver improved diagnostics on-site to able best mange the patient to a successful outcome. This project will address the feasibility of intelligent processing of the data from rapid (less than 5 mins.) from high sensitivity H-FABP diagnostic sensors. H-FABP is a highly sensitive early-rise marker of acute coronary syndrome (ACS), detectable as early as 30 minutes following the onset of an ischemic episode. This will allow higher quality management of CPR data. In order to develop this, data will be collected via UU's own FDA approved, specially developed wireless integrated devices, used impedimetric /optical transducers, which will feed data to a central encrypted secure system. All of this development will allow a responder performing CPR/defibrillation, to better define the condition of the patient before entering a hospital, thus enhancing the unique attributes of such a product via improved patient and cost-saving benefits. The project will attempt to identify the use of H-FABP devices and associated multiple datasets, to provide improved decision making, alerts and management at the CPR stages through to hospitalisation. Aims 1. To set-up and integrate sensing technology to specifically focus on CPR; 2. To perform key data-analysis of cardiac enzyme studies, in order to assess how key algorithms could provide advice at specific steps of the CPR procedure; 3. To determine the feasibility of high-resolution collection of h-FABP data to improve diagnostics, alerts and early-warning during the survival period by producing predictive trends against previous datasets thus allowing high levels of fast and accurate determination of the nature of the event. Anticipated Impact The Project Partners have expertise and access to fabrication and assembly of these sensing platforms. This study will provide a pathway to the development of new miniaturised, easy to use smart CPR diagnostics that will allow a clinician and eventually a carer/responder to train better, use an integrated device on-site for improved care and most importantly early warning of key changes in cardiac function during transportation to a hospital. Importantly this will allow prioritising of patients who have had an event ranging from cardiac arrest or chest pain to Myocardial infarction. Such a device will be low-cost, produce decisions within 5 minutes. The device would be stored alongside AED's for emergency use and also be core to feedback on new procedures associated with the full CPR survival phase.	3 years

Table 7.6: R&I Work Package 3 - Rapid Homecare Point of Care Diagnostics R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 11	Development of point-of-care (POC), rapid microfluidics-based diagnostic platforms for detection of cardiovascular disease:	DCU	There is a significant need for effective diagnostic systems for cardiac disease and, particularly, for early detection of potential cardiac arrest. Current approaches rely mainly on troponin I (TnI) determinations but lack adequate sensitivity and existing testing formats have issues with sensitivity and specificity. In addition, reliance on Tn I levels provides inadequate information. We have developed high sensitivity recombinant antibodies to key troponin epitopes and to other markers. In addition, we have established novel approaches for the incorporation of such antibodies into microfluidic-based centrifugal and other platforms that currently outperform established lab-based technologies. We will utilise panels of antibodies to selected biomarkers on a novel microfluidics platform to successfully address the current limitations in the detection of heart disease. <u>Aims</u> 1. Development, characterization and utilisation of high specificity and sensitivity recombinant antibodies to Troponin I, MPO, FABP, NTpro BNP and associated biomarkers of cardiac disease. 2. Incorporation of these antibodies on the developed microfluidics-based diagnostic platform and systems testing and optimization. 3. Preliminary validation and testing on patient cohorts. <u>Anticipated Impact</u> This project will provide Optimised antibodies for biomarker detection; Novel diagnostic platform for POC use; IP, peer-reviewed papers, posters, reviews, patents and presentations; Diagnostic platform and reagents for commercialisation; Enhanced patient welfare derived from earlier detection of potential cardiac arrests and associated cardiac diseases; Highly trained PhD students.	4 years
PhD 12	Point of care device for ultrasensitive detection of Mirna associated with cardiovascular disease	DCU	A multidisciplinary team Forster, (Ultrasensitive Electrochemical Detection), O'Kennedy (Biorecognition and Assay Development) and Collins (Microfluidic Devices) will develop a sample-to-answer device for the ***ultrasensitive, PCR free, multiplexed detection of low concentrations (sub-femtomolar) of miRNA biomarkers of theranostic value in CVD,*** including miR-126, miR-133, miR-143, miR-208 and the let-7 family. Novel, asymmetrically functionalized electrocatalytic metal nanoparticles will significantly amplify ($\approx 10^9$) the signal generated by biomarker capture allowing them to be directly detected. Multiplexing will allow a small panel of biomarkers to be detected thus improving early diagnosis as well as the monitoring of treatment efficacy and disease recurrence. <u>Aims</u> Create **electrocatalytic nanoparticles** capable of generating currents at least 10^6 times larger than the background where the target concentration is nanomolar or lower. Develop a **miRNA sandwich assay** where the target miRNA binds to a capture strand immobilized on an electrode and then the nanoparticles, functionalized with a nucleic acid sequence complementary to the unbound section of the target, become bound to the electrode and generate an electrocatalytic current. **Multiplex the assay** using an array of spatially separated electrodes each modified with a capture nucleic acid complementary to a particular miRNA target. Integrate the multiplexed assay within a **sample-to-answer microfluidic device**. The primary goal is to perform excellent research and provide outstanding training and education opportunities for researchers to make a demonstrable contribution to society and the economy. The project partners expect that each of the four primary aims will produce at least 2 publications in major journals such as JACS, Anal. Chem. etc. <u>Anticipated Impact</u> The main impact will be the ground-breaking advances in Ultrasensitive, Multiplexed and Multi-target Assays will lead to Low Cost, Near-Patient devices and enable the identification of at-risk individuals, the early detection of disease and the personalised tailoring of treatment based on the biomarker profile of an individual patient's disease through companion diagnostics.	4 years

Table 7.6: R&I Work Package 3 - Rapid Homecare Point of Care Diagnostics R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 13	Development of a Plasma Proprotein Convertase Subtilisin Kexin Type 9 (PCK9) Assay as a POCT Predictor of Atherosclerosis	DCU	Point-of-care testing (POCT) is necessary to provide a rapid diagnostic result for a prompt on-site diagnosis and treatment. Microfluidic lab-on-a-chip technologies have been considered as one of the promising solutions that can meet the requirement of the POCT since they can miniaturize and integrate most of the functional modules used in central laboratories into a small chip. Although traditional plasma lipid (e.g., LDL) and inflammatory factors (CRP) are important for the development of atherosclerosis, they do not fully account for the variation in risk of CVD. Hence, POCT detection of plasma markers associated with subclinical atherosclerosis will have important application for clinical practice. Proprotein convertase subtilisin kexin type 9 (PCSK9) is a secretory protease produced by the liver and detectable in human plasma. It plays a putative role in the development of atherosclerosis by regulating the expression of LDL receptor and hence the metabolism of LDL. <u>Aims</u> Engineer and produce a recombinant Fab antibody to detect proprotein convertase subtilisin kexin type 9 with high affinity for appropriate biorecognition Develop a POCT diagnostic test using proprotein convertase subtilisin kexin type 9 (PCSK9) as a surrogate marker for atherosclerosis. <u>Anticipated Impact</u> Cross-sectional studies of serum levels of PCSK9 are significantly related to subclinical atherosclerosis, independent of traditional risk factors and other inflammatory markers. Therefore, the development of a POCT that detects serum levels of PCSK9 as a part of a wider multiplex platform will greatly assist in patient risk stratification. The outputs will include knowledge dissemination through publications in high impact journals and presentations at international conferences, thesis defence and exploitation of the IP through the development of a POCT multiplex assay for CVD risk stratification.	4 years
PhD 19	Next-generation lateral flow diagnostics for home-based cardiac diagnostics	ST	This study will review and design new lateral flow-based methodologies for assessing heart failure via blood diagnostics in line with new Heart Failure medicine that is now entering the NHS. Heart Failure is the clinical syndrome can result from any structural or functional cardiac disorder that impairs the ability of the ventricle to fill with or eject blood. This area is well known to be associated with high levels of readmissions and there is a high possibility that a system can be developed to allow blood monitoring and therefore keep the patient from returning to the hospital. Such a project would also look at other parameters such as vital signs, weight and BP as indicators of improving or deteriorating health. <u>Aims</u> To evaluate new lateral flow biomarkers suitable for HF assessment and monitoring in the home. To optimise and specify the need and type of sensor requirement. <u>Anticipated Impact</u> New cardiac diagnostics is a major requirement to treat HF and prevent readmissions.	3 years

7.2.6 *Ambient Assisted Living (AAL) Home-Based Self-Management R&I Work Package*

Table 7.7: R&I Work Package 4 – Ambient Assisted Living (AAL) Home-Based Self-Management R&I	
Overview	**Key Anticipated Deliverables**
Over the past decade efforts within the domain of Ambient Assisted Living have strived from both research and industry perspectives to meet its original vision of improving quality of life and levels of independence. As a result, a plethora of solutions have evolved which have been influenced by decreasing hardware costs and the increased prevalence of mobile and pervasive sensing platforms. Nevertheless, a number of barriers still remain which have hindered its adoption on a large scale. Although the technological platforms are conceptually in place, effective processing and usage of the data being generated to stimulate behaviour change, at a truly personalised level are still missing. This coupled with the challenges of integration of new services within existing care delivery paradigms have hindered what many had initially viewed as the panacea to home-based care. This work package addresses the growing costs of domiciliary healthcare and the failing of improving the lives of our elderly (particularly isolated and rural – NI-ROI Border and UHI). There is a requirement for an improved approach to ADL. The Key research need is to establish a core infrastructure that ensures interoperability of systems, designed to allow scalability post-trial and evaluation phases in the design. Industry is seeking new ways to add more clinically relevant self-management systems in the smart home. Existing commercial interest is high around the concept of the design of new homes and the retrofit of old homes. The partner regions healthcare sector is striving to regulate better in the patient monitoring area, similar to how Energy has developed. The key challenges are scalability, clinical relevance in the collected data; establishment of relevant multi-jurisdiction standards, managing the storage and exchange of data. Ageing research within DkIT is led by the Netwell (Social Networks, Environments and Technologies for Wellness and Ageing-in-place) and CASALA (Centre for Affective Solutions for Ambient Living Awareness) research centres. Netwell/CASALA are working together in collaboration with industry, governmental bodies and other academic Institutes in developing new ideas that enhance the quality of life and well-being of older people and those who care for them, through more integrated community-oriented services, more sustainable home and neighbourhood design, and more age-friendly technologies. Netwell's mission is to promote Social Networks, Environments and Technologies for wellness and ageing-in-place. In conjunction with strong smart environment research at UU and UHI new clinically relevant challenges will be addressed around cardiac devices. PhD programmes will feed into the key platforms that will be delivered. These combined strengths to compete globally as many researchers and industrialists are keen to find innovative routes to add ease of use, robustness, smartness with user feedback to the patent and AAL environment. The key challenges for industry are therefore scalability, clinical relevance in the collected data (will it make a decision and is there a liability); establishment of relevant multi-jurisdiction standards and protocols, managing the storage and exchange of data. The related industry has identified key research need is to establish a core infrastructure that ensures interoperability of systems, designed to allow scalability post-trial and evaluation phases in the design. Industry is seeking new ways to add more clinically relevant self-management systems in the smart home. Existing commercial interest is high around the concept of the design of new homes and the retrofit of old homes. The partner regions healthcare sector is striving to regulate better in the patient monitoring area, similar to how Energy has developed.	1. Five PhD programmes will be undertaken; 2. A testbed and tool platform developed for cross border AAL type cardio-research established and validated, which will be underpinned by the associated PhD outputs, academic staff expertise and experience and a percentage of time input from the on-site PDRA. Anticipated to have an early-stage prototype platform by April 2018; a second stage platform demonstrator by March 2019 and an optimised platform demonstrator by March 2020. 3. Two-month industry placement for each PhD student. 4. One to many engagements with the following five organisations through the RA and BIM to refine and market test the platform through dissemination workshops, training and mini-projects. Businesses/organisations that were identified by the Project Partnership to potentially receive support included: • ST • Total Mobile • Intelesens • Kainos • HeartSine 5. Grant award to one to two businesses to assist in the development of next stage designs emerging from the new platform (subject to IP agreement); 6. Traditionally this activity has been less clinically orientated but throughout this programme, our cardiology team will review data and design of the AAL system; 7. To publish five peer-reviewed publications and theses (one per PhD student) by December 2021; 8. To prepare 11 other peer-reviewed publications (by supervising staff and academia within the wider project staff) by December 2021.

Summary of Ambient Assisted Living (AAL) Home-Based Self-Management R&I PhD projects

Table 7.8: R&I Work Package 4 - AAL Home-Based Self-Management R&I PhD Programmes

PhD Ref	Title	Based in	Description	Duration
PhD 5	Non-obtrusive sensing to assist post-stroke sufferers in home-based settings	UU	Home-based support for those recovering from a stroke has been proven to offer improvements in health recovery in addition to offering economic benefits. Technology-based systems have, however, suffered in their usability in addition to their long-term adoption by those using them. This project will focus on the development of an un-obtrusive sensing solution based on the aggregation of heterogeneous sensor technology to improve the support offered to those rehabilitating post-stroke. In addition, consideration will be given to the factors associated with the adoption of technical solutions with the goal of improving long term usage by potential users. This Project will be the first of its kind to contribute to the domain of un-obtrusive sensing within the home environment for those recovering post stroke. In addition, it will be the first project of its kind to embed intelligence in the self-management of home-based rehabilitation through alignment with the key stages of the behaviour change wheel. <u>Aim</u> To improve the experience of home-based users rehabilitating post-stroke through the usage of un-obtrusive sensing platform - to embed intelligence in self-reporting solutions to improve levels of technology adoption. <u>Anticipated Impact</u> The anticipated impact from this work will be recommendations on changes to the care pathways for those recovering from a stroke within home-based environments.	3 years
PhD 10	Workforce transformation in community care to vulnerable older people	DkIT	In the context of a population that is growing older, policy commitments to community care and emerging technologies that will change care practice, having a skilled and knowledgeable workforce caring for older people is an ethical and policy imperative. The majority of care to older people is provided by paid carers, yet little is known about the best way to facilitate their development to change care practice in the home and support technology-enabled care. This study will explore how workforce development interventions improve the skills and the care standards of workers within older people's health and social care services. <u>Aim</u> 1 To establish strategies for transforming community care for vulnerable older people, thereby supporting the development of a workforce skilled in person-centred, technology-enabled care. 2 To identify the skill sets care workers will need to develop to use and integrate technologies in the home and the challenges of integrating new technologies, thereby offering evidence-based scientific support to the policy-making process. <u>Anticipated Impact</u> The scientific impact on health and social care policy will include at least two articles or chapters of the thesis published or accepted for publication in scientific journals. The student will also participate in the broader scientific discussion including at least one international conference and contribute to public awareness through seminars in Ireland	4 years

Table 7.8: R&I Work Package 4 - AAL Home-Based Self-Management R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 14	Understanding critical stakeholders' perceptions and fears related to data-driven disease management opportunities in Cardiology	UCD	The advent of integrated electronic health records and personal sensing devices means we can now create a comprehensive longitudinal digital footprint for patients as they move throughout their lifespan and different interactions with the care system. The resultant data offers enormous potential for transforming care models. However, little is understood regarding the perceptions of different critical stakeholders (including patients and caregivers, clinicians, data scientists and service providers) with respect to important issues such as their understanding of the potential application models, how they would like to interact with this new digital world and see it fitting into their work/life patterns, how they feel about constant monitoring in the home, privacy and data control, and so on. In this project, we aim to conduct a deep ethnographic analysis of these issues through direct consultation with the different stakeholder groups in cardiac care. <u>Aim</u> 1. Conduct an extensive series of interviews with critical stakeholders in cardiac care, exploring issues related to data capture and usage. 2. Make recommendations for progress in the field based on the themes that emerge from this ethnographic exploration. <u>Anticipated Impact</u> From ethnographic analysis deliver a clear statement on critical stakeholders' perceptions and fears on data-driven disease management opportunities in Cardiology.	4 years
PhD 21	Fit homes: 3 years of Supervisors:	UHI	There is a need for well designed, affordable and sustainable housing within the cross-border area to address the demands of our social demographic. These homes will be made available for social rent through housing associations and social enterprise. The homes will be technology-enabled to allow ambient monitoring of home dwellers and the home itself. Monitoring can be combined with digital platforms which will allow home occupants to access and order local services themselves. The smart physical design of these homes will allow them to be adapted for changing care needs, including end of life care. This form of housing may enable early detection and intervention of illness and will facilitate earlier discharge of patients from hospital. <u>Aim</u> 1. To design and build modular, efficient and adaptable social housing. We will develop home and person-centred/controlled ambient monitoring systems. 2. To create highly secure data interrogations systems, which are acceptable to both the home dweller and the health and social care providers. <u>Anticipated Impact</u> Establish a collaborative, multi-establishment academic hub in the Cross Border are, creating expertise in technology-enabled housing. Assess the personal, societal and economic impact of these affordable and technology-enabled homes and develop commercial expertise in data warehousing, handling and analytics.	3 years

Table 7.8: R&I Work Package 4 - AAL Home-Based Self-Management R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 23	IBD Digital Health:	UHI	Long Term Conditions (LTCs) have a huge impact on the health and wealth of nations. Ambitious plans to improve the quality of care delivered to patients with LTCs will have a vicarious benefit on social care by increasing employment and educational opportunities. Inflammatory Bowel Disease (IBD) is a LTC that affects around 25,000 patients in Scotland (compared to 250,000 patients with diabetes) and 6,000 patients in Ulster and the border areas of Ireland. Its peak incidence is in the 20-40 years old age range. IBD is, therefore, a good exemplar LTC in which to test wholesale system change; discrete enough to limit risks but still ambitious in its scope. Aims 1 Deploy a unique digital health platform, designed, co-created and tested in Scotland and Ireland. We will integrate point of care testing and data from physiological wearable devices into the system. 2 To interrogate the Big Data generated using cutting edge data science for the benefit of all partners. Anticipated Impact Expand the capacity and capability of a range of SMEs and create strategies on which Scottish and Irish-based SMEs can do business with national health services and procure into it. Create the best practice in Open Innovation within the sector.	3 years

7.2.7 *Self-Management/ Rehab R&I Work Package*

Table 7.9: R&I Work Package 5 - Self-Management/ Rehab

Overview	**Key Anticipated Deliverables**
Cardiovascular disease (CVD) is the **leading cause** of premature death (30% of all deaths) and disability in Europe and worldwide (WHO), costing the EU economy almost EUR 196 billion a year. With changing demographics and deteriorating lifestyle this **situation will worsen considerably**, which is neither economically or socially sustainable. Effective Cardiac Rehabilitation (CR) can significantly improve mortality and morbidity rates, leading to longer independent living and reduced use of health care resources. However, **uptake of traditional community-based long-term (phase III) CR is very low** across member states (approx. 11%) and is further diminished by low subsequent adherence rates. Key reasons for this include severe lack of programmes, travel time, scheduling issues, lack of peer mentoring, and low self-efficacy associated with poor exercise techniques. WP5 constitutes a home-based lifestyle behavioural change programme that will adapt to a patient's progress through the CR program as well as providing feedback on this progress to both the patient and the clinician. The project partners intend to put in place a novel approach to CR that has the potential to address key limitations associated with the currently unsustainable provision of healthcare for CVD. Non-adherence to instructions, behaviour change and medication is a massive issue for the majority of health conditions. Personalising and predicting behaviour is critical to the success of self-management interventions. Algorithms can be developed for deployment at a sensor level to detect subtle changes in a person's vital signs/bloods, assess user behaviour within smart home environments to allow user profiling and to automate activity assistance-based systems for ADLs. Consultation with industry partners has indicated that the key trend is the need for patients to take control of their own health with the use of robust and smart technology platforms based on mobile phones. Existing commercial interest is very high, within NI/ROI and Scotland there has already been wide-ranging strategies, funding and industry development. The key challenge is to build data capturing tools and techniques which can source data to identify predicted behaviour's and build personalised responses to these behaviours. Backend cloud database management; data analytics, embedded systems, personalised medicine approaches and mobile systems are all key technological elements that require new leadership skills. PhD programmes will provide this important supply.	1. Five PhD programmes will be undertaken; 2. A software system with remote patient monitoring capability will be established for self-managing and rehabilitation purposes. Computational analysis and interrogation of platform databases: here effort will be directed towards the development of intelligent algorithms to process patient-related data with the desired target of understanding the user's behaviour or profile to allow the delivery of preventative based solutions. In the first instance, algorithms will be developed for deployment at a sensor level which will aim to detect, following personalised training, subtle changes in a person's vital signs. Secondly, algorithms will be established to assess user behaviour within smart environments/rehabilitation to allow user profiling and subsequently to be used as the input to automate activity assistance-based systems for ADLs. Thirdly and finally work will be directed towards the investigation of correlates between vital sign-based information and other sensor-based information to assess the possibility of hybrid approaches for ADL recognition and task completion. This work will be underpinned by the associated PhD outputs, academic staff expertise and experience and a percentage of time input from the on-site PDRA. Anticipated to have an early-stage prototype platform by April 2018; a second stage platform demonstrator by March 2019 and an optimised platform demonstrator by March 2020. 3. Two-month industry placement for each PhD student. 4. One to many engagements with the following six organisations through the RA and BIM to refine and market test the platform through dissemination workshops, training and mini-projects. Businesses/organisations that were identified by the Project Partnership to potentially receive support included: • ST • Total Mobile • Intelesens • Kainos • HeartSine • LifeScan 5. Grant award to one or two businesses to assist in the development of next stage designs emerging from the new platform (subject to IP agreement) 6. The clinicians at NHS Scotland and ST will assist in the design of clinical protocols, data evaluation and publication output. There will also be a requirement to supervise patient trails and data on various stages. 7. To publish five peer-reviewed publications and theses (one per PhD student) by December 2021; 8. To prepare 11 other peer-reviewed publications (by supervising staff and academia within the wider project staff) by December 2021.

Summary of Self-Management/ Rehab R&I PhD projects

Table 7.10: R&I Work Package 5 - Self-Management/ Rehab R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 4	In vitro cellular models to study the effects of waveform stimulation of cardiac tissue	NIBEC	Heart arrhythmias occur when there is a fault in the electric activity in the heart muscle, causing the heart to beat irregularly and in an uncoordinated way. Although there have been many advances in the diagnosis and treatment of these conditions, being able to prove their effectiveness (and safety) requires extensive pre-clinical and clinical assessment. Animal trials are central to such studies but recent and on-going changes to legislation on their use have significant implications for the future development of medical devices and therapies. Hence, there is a need to develop in vitro models that can replicate the function of tissues of the heart in a manner that can reduce and ultimately replace the need for animals in pre-clinical studies. In the case of a clinically effective model system, the key requirement is to produce a pseudo-tissue that can replicate the effects of stimulation of cardiac tissue and subsequently respond to treatments that involve the application of various energy waveforms to correct an arrhythmia. The approach taken here is to create a model of functional myocardial tissue via the combination of cardiomyocytes (heart cells) and a scaffold system (normally polymeric based). Aims Fabrication of bioresorbable polymer substrates via 3D Bioprinting methods that can support the adhesion, proliferation and differentiation of cardiomyocytes; Integration of sensor components capable of monitoring the response cardiomyocytes to external stimulation; Application of testing methods to predict the efficacy of the scaffold-based myocardial in vitro model system for AF detection. Anticipated Impact Will enhance stimulation of heart-related muscle across many applications	3 years

Table 7.10: R&I Work Package 5 - Self-Management/ Rehab R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 9	Empowering older cardiac patients through training towards the use of monitoring technologies for health and wellbeing self-management	DkIT	Worldwide, populations are ageing at a dramatic rate. These demographic trends demand us to reconsider how healthcare might be delivered to support older people managing chronic conditions at home. Monitoring technologies offer the opportunity for older adults to self-manage their health, putting them at the centre of their care. A key factor for the acceptance and continued use of these devices is training. This work will examine the factors and theoretical frameworks for how older adults would learn how to use monitoring technologies to manage chronic conditions in their home, and design training models to guide the delivery of future care. Aim To develop training models and techniques for learning to use monitoring technologies which considers the older learner's environment, family, community and healthcare providers. To empower older adults to self-manage health conditions, such as cardiovascular disease at home, through the continued use of monitoring technologies. Anticipated Impact The research would advance the current understanding of how and when training should be delivered to older people with chronic conditions. Outputs would include training models and material to guide the future delivery of technology-supported care. This research would have an impact for older patients giving them the tools and confidence to self-manage conditions independently at home, consequently reducing healthcare costs for the patient, family and state.	4 years
PhD 22	Diagnostic test for stratification of coronary artery disease risk	UHI	Assessing the relative risk of coronary artery disease developing into acute events is notoriously difficult, but is crucial in personalising a treatment that is proportionate to risk. Our recent work has shown that, in a retrospective study, certain epitopes derived from APO-B100 can be used to discriminate between levels of specific antibodies in patients with myocardial infarction (MI) compared to patients with coronary artery disease but no MI. There is now a need for a prospective study to confirm that the changes in antibody levels predict MI. Aims 1. To recruit coronary artery disease (without MI) patients from across the cross-border area to form a sufficiently large cohort to assess. 2. To measure antibodies in patients at recruitment, with follow up at year 1 and 2. Anticipated Impact To create a clear position on if certain epitopes derived from APO-B100 can be used to discriminate between levels of specific antibodies in patients with myocardial infarction (MI).	3 years

Table 7.10: R&I Work Package 5 - Self-Management/ Rehab R&I PhD Programmes				
PhD Ref	**Title**	**Based in**	**Description**	**Duration**
PhD 24	Cardiac Rehabilitation in the community	UHI	Cardiac rehabilitation is a crucial element of the treatment of patients following a cardiac event or an interventional cardiology procedure in patients with coronary artery disease. Cardiac rehabilitation is associated with a 25% reduction in mortality over three years and is recognised to improve quality of life, but the services are generally underused and there are questions over whether programmes should be delivered in a hospital or in the community to improve compliance. This proposal is a joint venture between UHI, NHS Highland and Highlife Highland, which develops and promotes opportunities in sports, leisure, health and wellbeing across the Highland region. The concept is to train fitness instructors in cardiac rehabilitation techniques to facilitate rehabilitation programmes to be delivered in the community across the distributed population of the Highlands of Scotland. <u>Aim</u> Potential benefits of the intervention in patients with MI or heart failure or both will be assessed using validated quality of life questionnaires, together with interim biomarkers for inflammation and fatigue. The project aims to improve cardiac rehabilitation delivery and patient outcome in a largely rural population. <u>Anticipated Impact</u> The concept is to train fitness instructors in cardiac rehabilitation techniques to facilitate rehabilitation programmes to be delivered in the community across the distributed population of the Highlands of Scotland. Potential benefits of the intervention in patients with MI or heart failure or both will be assessed using validated quality of life questionnaires, together with interim biomarkers for inflammation and fatigue.	3 years
PhD 8	Ambient Assisted Living for Cardiovascular Disease Exercise Compliance,	XX	In Ireland, approximately 10,000 people die each year from cardiovascular disease (CVD). CVD is the most common cause of death in Ireland, accounting for 36% of all deaths. Ambient Assisted Living aims to use ICT technologies to allow older people to age in place while increasing their quality of life. Continuous monitoring of blood pressure via wireless monitors has been used to assess CVD risk. We will assess how ambient sensors can be used to track patients' adherence to recommendations for improving their cardiovascular health. <u>Aims</u> 1. Can ambient sensors track patients' adherence to dietary and physical activity recommendations to improve their cardiovascular health? 2. Can ambient sensors improve patients' adherence to dietary and physical activity recommendations to improve their cardiovascular health and improve patient outcomes? <u>Anticipated Outputs - scientific and impact</u> 3 conference papers and one journal paper. This research will assess whether people with CVD can be encouraged to self-manage their condition by managing diet and exercise. The Project Partners hope this will lead to an improvement in adherence to recommendations which will lead to improved health outcomes.	4 years

7.2.8 Research Associates - Platform Development and Refinement

It is envisaged that the three RAs will undertake to develop five demonstrator platforms that will seek to, through an anticipated three reiterations with industry (feedback and mini-projects) and informed by PhD emerging findings, improve the specificity and/or sensitivity and/or false positive ratings of the demonstrator to a rate that is acceptable to industry e.g. typically 95% sensitivity as the basis of future product development.

The expectation is that the industry partners, through an open-access approach, would then take the demonstrator in house to customise and develop new products. Similarly, PhD and RAs will be supported by the Office for R&I to consider the spin-out option.

7.2.9 Summary of TRL and Industry Engagement by Technical Work Package

The following TRL (Technology Readiness Levels) and industry engagement are envisaged by work package:

Table 7.11: TRL Levels of each Work Package

WP	PhD TRL		RA Platform TRL		Potentially core Industry and Clinical Collaborators
	PhD at Project Start	PhD at Project End	RA at Project Start	RA at Project End	
1. Cardiac Data Analytics	TRL 2	TRL 4	TRL 3	TRL 6	ST, Randox, Heartsine, Intelesens, Kainos, Armstrong Medical.
2. Smart Wearables	TRL 3	TRL 4	TRL 3	TRL 6	ST, Intelesens, CIGA, Epona, Heartsine, Abbott.
3. POC Diagnostics	TRL 1	TRL 4	TRL 2	TRL 6	ST, JandJ, Abbott, Epona, Randox, SiSaf, Armstrong Medical, JandJ, LifeScan.
4. Ambient Assisted Living – Cardio	TRL 3	TRL 5	TRL 3	TRL 6	ST, Total Mobile, Intelesens, Kainos, Heartsine.
5. Self-Management/ Rehab	TRL 3	TRL 5	TRL 3	TRL 6	ST, Intelesens, Heartsine, Total Mobile.

7.2.10 Business Integration / Engagement with Industry

Industry partners are core to the project, and it is anticipated that they will be well placed to benefit from participation in a Business Integration Scheme which will consist of one-to-many engagements through workshops and training that directly links to the PhD research emerging findings and topic area. The training will have four strands:

1. Commercial Processes Training within Sector (Business models, interaction with Universities and Hospitals, clinical trials, adoption and procurement);
2. IP Development;
3. Knowledge Transfer Training (Regulatory, Proto-typing and Research Skills); and
4. Process Development Training (utilising best practise techniques emerging from the research).

7.2.11 Student Industry Placements (with and without mini project)

The 24 PhD students will benefit from a final year industry placement; of which:

- 10 will be matched with industry partners to undertake a mini-project. Mini projects, as delivered through a PhD placement in 10 criteria-compliant businesses, will be informed by the work of the RA in the development of the platform; subject to approval by the Management Board. The expectation is that these projects would be more speculative and next-generation than the mainstream planned work of industry partners.

The expectation is that the companies would be awarded an average grant of £30,000 to cover their costs of input into the mini-project. Anticipated eligible spend would be for the following:

- Consumables;
- Instrumentation;
- Travel and subsistence;
- Staff time;
- Sub-contractor costs e.g. prototyping;
- Tailored training

- On the basis that there would not be enough capacity in businesses to place all students into a mini project industry placement, the remaining 14 will be placed with the identified industry partners for a period of two months.

The decision as to which businesses will qualify for the mini-project placement will be undertaken by the Management Board against the following indicative business integration criteria:

1. Demonstrable and robust rationale as to how the mini-project will leverage economic benefits;
2. Strategic fit with the business' R&D strategy;
3. Appropriate structures in place to manage the PhD-led mini-project.

7.2.12 Dissemination Strategy

The Project Partners state that all results and outputs will be disseminated as widely as possible, with a knowledge base developed which will be shared with industry. The project partners also intend to attend, as a group, large EU, Asian or US conferences/trade shows to demonstrate the impact of the team.

Joint publishing in world-class journals and keynotes at International Conferences; Joint- exchanges; Joint Training (Specialist, academic and commercial); Joint Grant Writing; Visiting Professorships; Equipment access etc., are all anticipated to be key elements of collaboration.

Internally ECME staff/students will use Basecamp and PR will be the responsibility of the PI and PD and in line with the respective Partners.

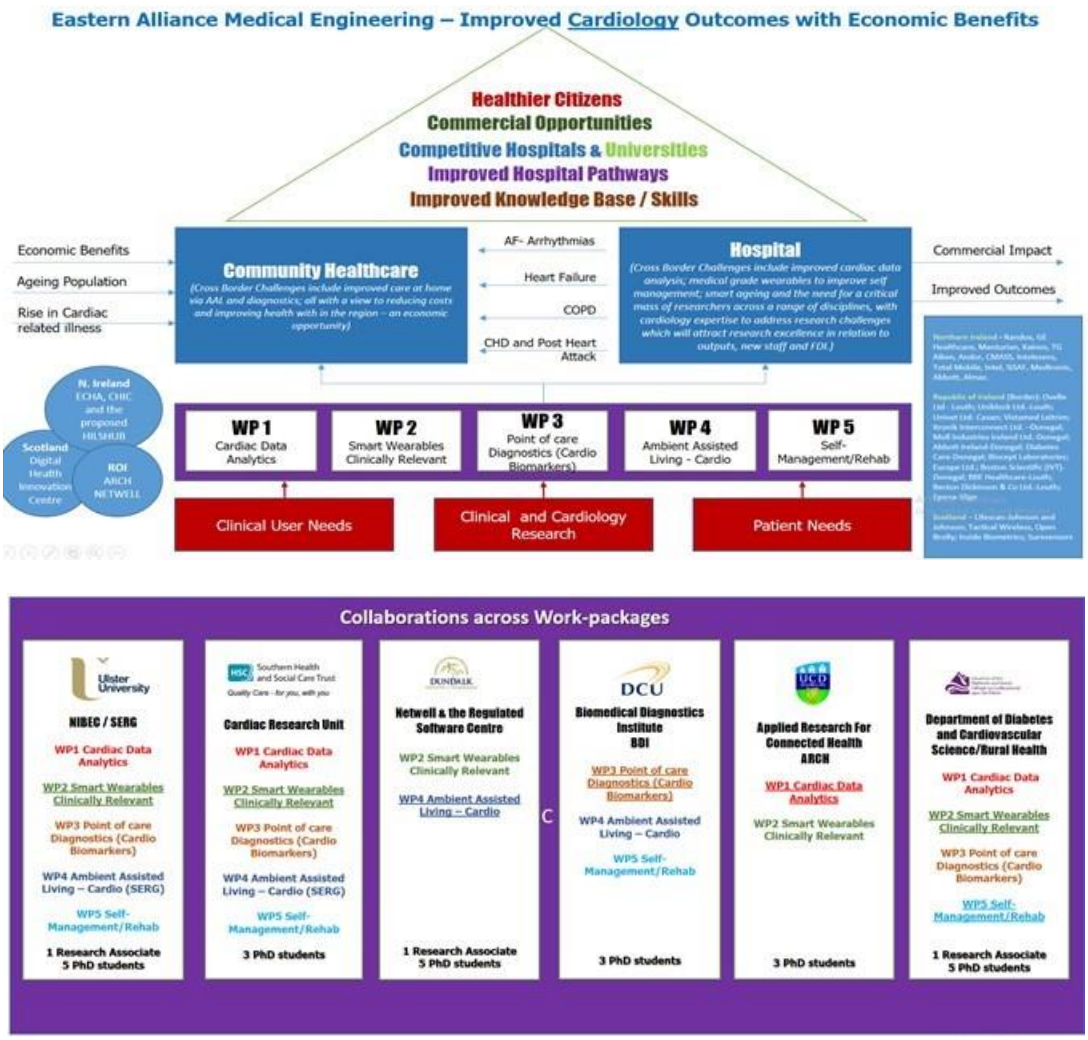
The anticipated PhD dissemination strategy activities include:	• 81 publications in high impact international peer-reviewed journals • Every PhD student will be expected to produce a minimum of one peer-review standard academic paper during the ECME programme; as well as one thesis. The 24 theses will be published in a book, which will be made available to the major stakeholders. • Conferences: Lead conferences have been identified in each of the disciplinary domains and PhD students will be expected to present at the doctoral colloquia of these conferences. • Working alongside Joining European Associations: ECHA and ENJECT COST action, to build an international structure for connected health and medical engineering researcher development. This will give the opportunity to network with related industries and lobby to European Policymakers. PhD students will be able to attend these COST events and showcase their results. • Non-scientific Articles: For example, industry magazines that look at new innovations in the digital health sector. ESRs will be required to publish these non-scientific articles to further develop their communication skills and capture a wider audience beyond an academic setting.
The anticipated RA/ innovation dissemination strategy policies include:	• Ensuring no IP/proprietary disclosure is made without full permission and adherence of programme leaders. • Partner leads will ensure their websites are kept up-to-date and researchers will ensure their research outputs are routinely deposited in the publication database, which provides a live-feed to the main EAME webpage. All staff profiles and activities will also be kept up to date.

	• Optimal use of social media and development of YouTube channel for training; capturing significant events or discovery. • Staff will provide information relating to success in obtaining research funding, awards, completed or forthcoming research outputs, events hosted by them, conference attendance, consultancies and other indicators of esteem. • All communication will be managed by Basecamp and the administrative team will ensure that highlights are continually broadcasted internally and if permitted externally on a regular basis.

7.2.13 ECME Project Management

An overview of the proposed project structure, partners, drivers and outputs is provided below:

Figure 7.1: The overall structure, partners, drivers and outputs of ECME.



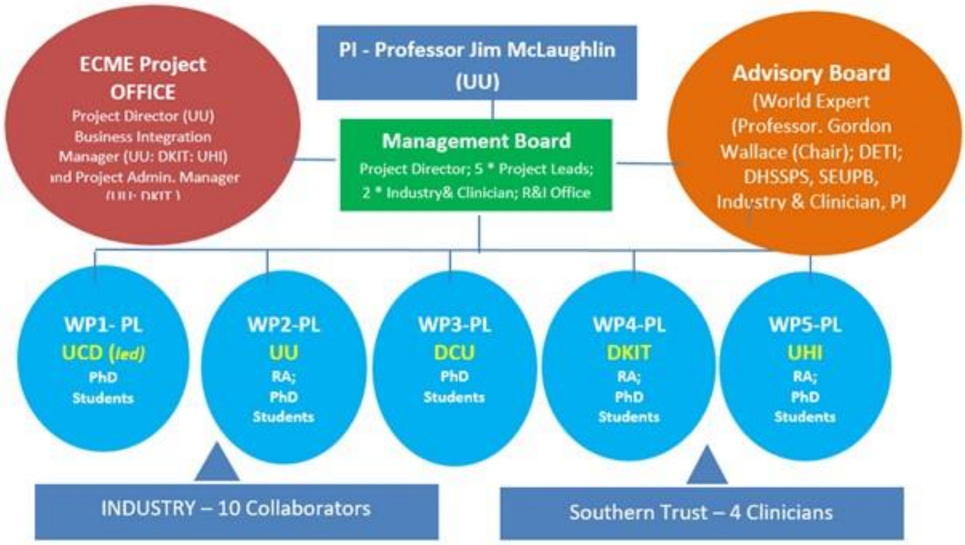
The project has an Advisory and Management Board to provide strategic and operational direction and challenge to the Principal Investigator and his team. There is an agreed terms of reference for each board:

- The Project Management Board (PMB) will oversee the five work packages and will meet on a quarterly basis to consider progress against work plan anticipated milestones, quarterly progress reporting, etc. Membership of this project board is drawn from representation from all partners, as well as two industry representatives and Research Office representatives.
- The Advisory Board (AB) consisting of World Expert – Professor Gordon Wallace University of Wollongong (Sensors and Proto-typing); Professor George Crooks DH -Scotland; Dan Maher - Nua Ventures-Dublin; Industrialist – Dr John Lamont Randox; Clinician Cardiologist Dr David

McEneaney (ST); Innovation- Prof. Norman Apsley NISP-Catalyst Inc and DfE/DoH/SEUPB representatives will meet annually to review and internationally benchmark the project.

The key staff for the project are academia – with 24 PhDs and three RAs across the five technical work packages, and the overall project research lead is the Principal Investigator (Prof. McLaughlin, UU).

Figure 7.2: ECME Management Structure



The project has a dedicated project office at UU, the lead partner. The staff undertake the following roles:

- **Project Director** – This staff member is responsible for leading the day-to-day activities of the overall centre. Key responsibilities include providing reports; overall finances; promoting the activities of the centre; seeking future funding and leading the centre to a sustainable and high impact future.
- **Business Integration Manager** (BIM) – Responsible for liaising with Industry Partners; providing information; IP and state aid advice, encouragement; checking milestones; setting up training, visits and workshops and IP scanning. The BIM will be responsible for running an intense 'Business Integration Scheme' which will fund awards with a total budget of £300k.
- **Project Administration Manager** – Responsible for finance administration such as procurement; transaction validation; claims; timesheets; liaising with claim auditors/validators; organisation of meetings/events/training; PhD supervision administration and overall integration of services.

The project relies on existing staff for supervision of PhD students and for assistance from the Office of R&I in project dissemination.

In addition to the above, the financial management of the project will be the responsibility of UU's Research Office / Finance Department.

The Project's seven work packages are summarised below:

Table 7.12: Project's seven work packages

WP	Work Package	Platform (where relevant)
1	Management	
2	Cardiac Data Analytics	Development of a cloud-based platform of cardiac based data storage and analysis tools
3	Smart Wearables	Development of a state-of-the-art platform to allow the development of commercial medical device grade wearable technology.

Table 7.12: Project's seven work packages		
WP	**Work Package**	**Platform (where relevant)**
4	Ambient Assisted Living	Development of testbed and tools for cross border ambient assisted living cardio-research.
5	Self-Management	Development of a software system with enhanced remote patient monitoring capability.
6	POC Diagnostics	Development of a microfluidic platform for general testing, blood collection and filtering
7	Communication	

7.3 Project Budget

The ECME project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €8,151,717.53 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,362,917.13, as summarised in the tables below:

Table 7.13: Anticipated Project Costs	
Summary Budget	**Total Project Costs (€)**
Staff Costs	1,823,867.08
Office and Administration Costs	1,442,750.16
External Expertise and Services	4,458,184.67
Travel and Accommodation Costs	137,306.17
Equipment Costs	500,809.05
Total	**8,362,917.13**

Table 7.14: Anticipated Project Funding	
Funding Sources	**Total Value (€) (Public)**
Cash Contribution (Partner Supplied/other grant)	211,199.60
Government Match Funding	1,043,238.00
ERDF	7,108,479.53
Total Grant Funding	**8,151,717.53**
Total Project Costs	**8,362,917.13**
Intervention rate (% ERDF)	85%

7.4 Anticipated Project Objectives, Outputs and Results

7.4.1 Project Objectives

The project partners have established the following project objectives/SMART targets:

Overall Programme[78]

1. To create a cross-border centre of research competence and excellence within the field of cardiovascular medicine by March 2017, in particular focusing on medical-grade wearables and associated remote monitoring systems;
2. To undertake excellent research (commencing at TRL levels of between 1 and 3), through the creation of 24 PhD studentships aiming to have all research PhDs completed by December 2021;
3. To engage with ten industry partners at TRL levels of between 2 and 6 through three Research Associate appointments in five RIs and one Business Interface Manager; with funded innovation activity completed by December 2021[79].

[78] Per LoO (dated 21 June 2017)
[79] The Evaluation Team notes that the project's application for funding also noted that the following **additional enterprises** are anticipated to benefit from knowledge exchange events: **Northern Ireland** (8): Marturion, TG Aiken, Andor, Analytics engines, SurfSpec, CMASS, AMS and Almac. **Republic of Ireland** (Border) - (14): Ovelle Ltd;

NB at the time of its application, the following 10 businesses had already confirmed their participation.

Table 7.15: Confirmed Industry Collaboration

Enterprise Name	Jurisdiction	Size Classification	Type of Intervention		Grants
			Support	**Non-Financial Support**	
Randox	NI	Large	✓	✓	Not yet known until Years 3 to 5
Intelesens	NI	SME	✓	✓	
Kainos	NI	SME	✓	✓	
Heartsine	NI	SME	✓	✓	
CIGA	NI	SME	✓	✓	
Armstrong Medical	NI	Large	✓	✓	
SiSaf	NI	SME	✓	✓	
Abbott	ROI	Large	✓	✓	
Epona	ROI	SME	✓	✓	
JandJ	Scotland	Large	✓	✓	
Total			**10**	**10**	**5**

However, it should be noted that, during consultation, the Project Partners noted that due to emerging developments within the sector, and particularly with the growth of Artificial Intelligence (AI), the nature of businesses receiving support may ultimately change vis-à-vis those identified at the outset.

4. To publish 81 peer-reviewed journal and conference publications with cross-border authorship, to increase international recognition of the centre by December 2021;
5. To create five new product platforms (generic technologies that allow both academic and industrial research to be progressed on for a wide range of applications – for example, a versatile microfluidic system or a robust software algorithm/app) by December 2021 that will provide the building blocks for future commercialisation of the research.

Business Integration[80]

1. To engage with at least 20 companies in the health and life sciences sector from within the eligible region through nine structured training workshop events commencing in October 2017 and completing in October 2021. Sample themes include IP development, new product platform development and process development.
2. To place 14 PhD students within industry partner organisations for a period of two months, with all placements completed by December 2021.
3. To place 10 PhD students within industry partner organisations to undertake a mini project related to commercialisation of the platform demonstrator, with all mini-projects completed by December 2021.
4. To continuously scan for intellectual property and license opportunities throughout the research and innovation activities undertaken, with information collated in the monitoring reports collated.
5. Built on the principles of Lean Start-Up to bridge the gap between academia and industry through the placement of all 24 PhD and 3 RAs onto the Lean Start-up Programme "Long Thin Course" between November 2018 and May 2019.

7.4.2 *Outputs and Results*

It is anticipated that the ECME project will contribute to each of the output indicators stated for Thematic Objective 1 call of INTERREG VA as detailed below in Table 4.16.

Uniblock Ltd; Univet Ltd; Vistamed; Itronik Interconnect Ltd; Moll Industries Ireland Ltd; Diabetes Care; Biocept Laboratories; Europe Ltd; Boston Scientific (IVT); BBE Healthcare; Medtronic; Intel and Becton Dickinson. **Scotland** (4): Tactical Wireless, Open Brolly; Inside Biometrics; Suresensors.

[80] Per Stage 2 Application

Table 7.16: Proposed Project Output Target										
Output Indicator	Description	Programme Target	Approved Project Output Target							Notes
			WP1	WP2	WP3	WP4	WP5	Total	ECME's % of Total	
C001	No. enterprises receiving support	20	10	10	10	10	10	**10**	50%	10 businesses, all of which are within the eligible region, directly receiving non-financial support through workshop, training and industry placements of PhDs; as well as engagement in the development of the platform demonstrators (out of which intellectual property will emerge and be managed)
C002	No. enterprises receiving grants	10	1	1	1	1	1	**5**	50%	5 businesses, all of which are within the eligible region, directly receiving grants to innovate as a direct offshoot of the platform demonstrator developed within each work package. The grants will be subject to State Aid considerations. There is an overall budget allowance of £300,000, for the development of prototypes, market testing, etc. of newly developed product platforms.
C004	No. enterprises receiving non-financial support	20	3	4	4	4	3	**10**	50%	
C024	No new researchers in supported entities	514	19	19	19	19	19	**95 FTEs**	18.5%	• 83 FTEs through 24 PhDs that have the added value of being mobile between RIs and undertaking an industrial placement and Lean Start Training; • 12 FTEs through 3 RAs that have the added value of being mobile between RIs and responsible for delivering five platform demonstrators.
C026	No. enterprises cooperating with RIs	10	5	4	5	5	4	**10**	100%	
C041	No. enterprises participating in cross-border research projects	10	5	4	5	5	4	**10**	100%	
C042	No. research institutions participating in cross-border research projects	10	5	5	5	5	5	**5**	100%	

Researchers will be recruited on variable-length contracts by each project partner. The following table sets out the annual FTE allocation by Research Institute (of which there are five – SE Trust PhD students will be supervised primarily through UU):

Table 7.17: FTEs Per Partner and Work Package																		
RI	PhD FTE Years[81]						Post Doc FTE Years						Total FTE Years					
	1	2	3	4	5	Total	1	2	3	4	5	Total	1	2	3	4	5	Total
UU	3	5	5	2	-	**15**	1	1	1	1	-	**4**	4	6	6	3	-	**19**
DKIT	3	5	5	5	2	**20**	1	1	1	1	-	**4**	4	6	6	6	2	**24**
DCU	2	3	3	3	1	**12**	-	-	-	-	-	-	2	3	3	3	1	**12**
UCD	2	3	3	3	1	**12**	-	-	-	-	-	-	2	3	3	3	1	**12**
SE	2	3	3	1	-	**9**	-	-	-	-	-	-	2	3	3	1	-	**9**
UHI	3	5	5	2	-	**15**	1	1	1	1	-	**4**	4	6	6	3	-	**19**
Total	**15**	**24**	**24**	**16**	**4**	**83**	**3**	**3**	**3**	**3**	**-**	**12**	**18**	**27**	**27**	**19**	**4**	**95**

[81] The duration of the PhD studentships varies by university. Typically, 3 years in UU and DKIT; and 4 years in DCU, UCD and UHI

Results

It is anticipated that the project will contribute 81 peer-reviewed journal and conference publications with cross-border authorship. It is anticipated that each of these publications will be excellent in status, as defined by the REF system in the UK and the HEA Research Review system in the ROI.

It is anticipated that the journals to which papers will be submitted will include Journal of Electrocardiology; European Journal of Cardiology; Journal of the American Heart Association; Computers in Cardiology; IEEE Biomedical Engineering; Blood; Nature; Sensors and Actuators, Biosensors; Biosensor and Bioelectronics etc. The Conferences to be attended include The International Society for Computerized Electrocardiology (ISCE); pHealth, IEEE EMBS, ICBME and MicroTAS. In all cases, new journals will be formatted under UU's Open Access Policies.

The anticipated outcome of ECME will be to create better models of heart disease care by researching (through 24 PhD students) and developing generic solutions (through 3 RAs) within the lucrative and growing remote patient monitoring market, with a specific focus on developing cardiac big data database within the region; enhancing user ready sensor technology; improving smart wearables; reducing the complexity and cumbersomeness of point of care diagnostics and improved smart clinically relevant monitoring in the AAL and rehabilitation environments. Given this, a further anticipated result of the proposed project will be potential economic impact. It is anticipated that the proposed project will result in the following outcomes to varying extents within each of the three programme jurisdictions:

- Increased annual BERD by the enterprises supported (Baseline: to be determined);
- Increased research capability rating of the participant universities (Target to increase Research Quality (HEFCE-GPA increased by 10%) and HEA performance by 10%);
- Increased future R&I funding for the sector;
- Development of five new product platform demonstrators aligned with the technical work-packages, with export potential;
- Increased number of jobs in the high-value Health and Life Sciences sector through the creation of university spin-outs (Target: 5);
- Reverse brain drain - PhD graduates in employment with industry in the region in the post-project period (Target: 8)[82]
- Enhanced sales and GVA from innovative solutions developed (outside the programme timeframe);
- Growth of the regional R&D support infrastructure associated with fundamental and applied interests in health and life sciences, engineering innovation and manufacturing.

7.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the ECME project's key achievements (as of November 2018[83]) and the extent to which the ECME project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

[82] Baseline: UU Faculty of Computing and Engineering PhD Leaver Survey 2015 – 17% into industry and 69% into research roles
[83] Please note that the key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing.

7.5.2 *Key Achievements (to November 2018)*

The ECME project partners cite the project's key achievements (as of November 2018) as being:

Table 7.18: Key Achievements

Period	Dates	Key Achievements
1	1st March 2017 – 31st May 2017	• The first draft of the partnership agreement was prepared. • The PhD supervisors met to discuss the proposed PhD topics and finalise the titles.
2	1st June 2017 – 31st August 2017	• Meetings via Zoom, telephone and email to progress the Partnership Agreement; • Clarifying the PhD projects and initiating the recruitment process via web advertising; • Holding interviews and selecting PhD students; • Launching website
3	1st September 2017 – 30th November 2017	• During this period further recruitment was carried out across all the partners. Along with the recruitment of research staff, Dr Paul Beaney was appointed as Project Manager. • The partnership agreement was signed. • Research commenced on some of the projects and planning was started on how the project will deliver the required publications. • The project also created its first sensors which are microneedles used to monitor blood composition.
4	1st December 2017 – 28th 31st February 2018	• During period 4, many of the PhD researchers started to carry out their literature reviews and in some cases started to carry out experimental work and the writing of research papers including the creation of a conference paper on Unobtrusive Sensing for Home-Based Post-Stroke Rehabilitation. • The recruitment of the PhDs was almost complete, and the only staff appointment outstanding was the Business Interface Officer.
5	1st March 2018 – 31st May 2018	• The project started to see the creation of some prototype devices including microneedle patches that can test the blood just under the skin painlessly and potentially evaluate cardiac health risks.
6	1st June 2018 – 31st August 2018	• During this reporting period, the PhD researchers started the training and networking and many had also produced some lab-based outputs. This has included the formation of a training networking committee and associated base camp group. • The project team continued to plan the first large-scale event in DCU which was anticipated to bring together all project staff and potentially industry collaborators. The goal of this event was to bring project team members together and start to plan the creation of the platform technologies.
7	1st September 2018 – 30th November 2018	• On the 4th and 5th of October, the project partners held their first major internally focussed event focused on launching the cross-border research aspects of the project. The event • 21 of the 24 proposed PhDs were in post and were considered, by the project partners, to be making good progress.

Key progress (at November 2018) by each of the five technical work packages is summarised below:

Table 7.19: Key progress of the five technical work packages

WP	Title	Progress (at November 2018)
2	Cardiac Data Analytics	This work package was largely on track with researchers carrying out the initial phases of their research projects. However, there has been a delay in the recruitment for one of the PhD projects. The project partners anticipated that they would recruit a researcher during the period December 2018-February 2019. To this end, the project partners were actively looking for ways to attract high-quality researchers and were sharing best practice.
3	Smart Wearables	This work package was on track and all PhD researchers have been recruited and were considered to be making satisfactory progress. A PDRA had been granted ethical approval to conduct a study that will evaluate measurements of heart rate, sleep and activity from smart wearables with older adults living in a nursing home environment.
4	Ambient Assisted Living	The PhD researchers have been working on their literature reviews and planning out the initial phases of their research.
5	Self-Management	All 4 PhD researchers and the PDRA had been recruited.
6	POC Diagnostics	The PhD researchers had, in most cases, made a start on their literature review and were planning out the initial stages of their research.

Key progress (at November 2018) by each of the PhD projects by work package is summarised in Table 7.20 to 7.24 below:

Table 7.20: WP2 - Cardiac Data Analytics		
No.	**Title**	**Progress (key highlights)**
PhD 3	Development of Multi-Parameter Models for Rapid Diagnosis and Treatment of Cardiovascular Disease	• The PhD researcher has carried out interpolation to substitute the missing data in body surface maps using a new method that combines Laplacian interpolation and principal component analysis-based interpolation. The Project Partners consider the results to be encouraging with regards to their ability to non-invasively determine the electrical activity of the surface of the heart. This could assist with the diagnosis of various related heart conditions. A conference paper has been prepared in Computing in Cardiology to present the preliminary results.
PhD 6	Connecting Medical Devices to an IT network – Risk Management and Security	• This project is focused on the security implications of connecting IoT type devices to various types of networks and the inherent challenges this brings. The PhD completed the research to map relevant Cybersecurity standards and wrote a report to enable the selection of the relevant standards to be studied within the PhD project. • At May 2019, PhD6 was continuing work on medical standards and preparing a conference paper.
PhD 7	Designing behaviour change interventions to support older adults managing cardiac conditions	• The PhD researcher submitted an application to the HSE North East Area ethics committee for Phase 1 fieldwork. The ethical approval was granted, which is a key step for the project and allows the study to commence. The PhD researcher was also working on a systematic review and preparing a study protocol for phase 1 fieldwork. • PhD7 was also working with a PDRA to develop a wearable platform technology that will measure a number of physiological measurements. • At May 2019, PhD7 had completed interviews and focus groups as part of phase 1a study.
PhD 17	In-silco personalised patient modelling for better outcomes and interventional procedure planning	• The first PhD researcher was considered to have made good progress in understanding the research problem and starting to identify how the AI-based resuscitation algorithms could be developed. • The PhD also attended the RE-WORK Deep Learning in Healthcare Summit in London, Sep 2018 as an invited exhibitor. • The second PhD researcher had only registered and was due to get started on her research in January 2019.
PhD 19:	To determine if CIMIT can perform as well as CAC in the prediction	• At November 2018, this project was being recruited for.
PhD 14	Development of multimodal data warehouse and data mining platform for shared cardiology datasets	• The researcher was designing and developing a data warehouse and data mining platform that facilitates the storing and the analytics of medical datasets. • The student has completed training (CITI Human Subjects), which is related to human subject research, as it is highly required in order to work on a public dataset.

Table 7.21: WP3 - Smart Wearables		
No.	**Title**	**Progress (key highlights)**
PhD 2:	Remote Telemetry of Oxidative Stress Processes in the Management of Stroke: Acquisition and Processing of Metabolomic Data	• The PhD was continuing her work on assessing the use of carbon composite microneedles for the detection of uric acid (a general cardiovascular biomarker).
PhD 15:	Development and Evaluation of mobile-based adaptive training programme for patients with cardiac conditions.	• The student has completed the initial screening for a systematic review on the use of technology to support rehabilitation and self-care following cardiac surgery. • It was anticipated that the ethics application for this study will be submitted during Q2 2019.
PhD 16:	Development and Evaluation of mobile-based monitoring programme for Congestive Heart Failure – focusing on patient-generated data	• At November 2018, this researcher was stated to be on a leave of absence. However, it was considered that they had made satisfactory progress up to that stage.
PhD 20:	Point of Care detection of asymptomatic atrial fibrillation	• At November 2018, this studentship had been offered and a visa has been obtained for the student, who was anticipated to start on 1st December 2018.
PhD 18:	Implantable devices meets the medical internet of things	• The initial stages of the PhD research project had been undertaken and knowledge of the ultrasound-based techniques for arterial wall measurements has been investigated.
PDRA	Wearables Platform Demonstrator (including engagement with industry)	• The PDRA presented at the ECME workshop in DCU regarding the platform technology.

Table 7.22: WP3 - Ambient Assisted Living		
No.	**Title**	**Progress (key highlights)**
PhD 5	Non-obtrusive sensing to assist post-stroke sufferers in home-based settings	• The PhD has investigated a number of sensing options and has started with the development of a framework to fuse 2 sensors. • The researcher has created a test system where a user's movements can be traced by the fusion sensor system and check this is being done correctly using a reference avatar.
PhD 10:	Workforce transformation in technology-enabled community care to older people with cardiac conditions	• Proceeding according to the work plan; • At May 2019, PhD10 had completed interviews and focus groups as part of phase 1 study.
PhD 21:	Fit Homes	• Proceeding according to work plan
PhD 23	Precision markers for contrast-induced nephropathy	• The researcher had completed a literature review and was planning (at November 2018) the study that would form the main part of their PhD research.
PhD 8	Ambient assisted living for cardiovascular disease dietary and physical activity compliance	• The PhD started the training aspect of the project and has completed tutorials on machine learning and working on the literature review required to gain expertise in the field of study. • Ay May 2019, PhD8 was developing machine learning analysis skills through training

Table 7.23: WP4 - Self-Management		
No.	**Title**	**Progress (key highlights)**
PhD 4:	Waveform stimulation optimisation with an AF cellular model	• A range of PCL and PCL/Graphene scaffolds had been successfully printed from the CAD-based 3D scaffold designs of interest. A number of planned studies have been conducted on these substrates.
PhD 9	Empowering older cardiac patients through training towards the use of monitoring technologies for health and wellbeing self-management	• The original PhD research resigned from at the start of September 2018. • At May 2019, a new PhD9 had been recruited and was due to commence during September 2019.
PhD 22	Diagnostic test for stratification of coronary artery disease risk	• The researcher had completed a literature review and was planning (at November 2018) the study that would form the main part of their PhD research.
PhD 24	Cardiac Rehabilitation in the Community	• The researcher had completed a literature review and was planning (at November 2018) the study that would form the main part of their PhD research.

Table 7.24: WP5 - POC Diagnostics		
No.	**Title**	**Progress (key highlights)**
PhD 1	Point of care device for ultrasensitive detection of Mirna associated with cardiovascular disease	• The researcher was (at November 2018) completing their literature review and had started to create the ECG platform device which he intended to use for most of his work going forward.
PhD 11	Development of point-of-care rapid microfluidics-based diagnostic platforms for the detection of cardiovascular disease	• The PhD researcher had published (MDPI's Biosensors Journal) a paper on the compatibility of ultrasensitive detection techniques for POC testing with an emphasis on CVD. • He had also selected a suitable immobilisation method for the antibodies. He had designed a pump for potential sample delivery within the microfluidic chips. The pump is critical for controlling the delivery of the sample.
PhD 12	Point of care device for ultrasensitive detection of miRNA associated with cardiovascular disease	• Inks based on biocompatible components were being prepared for the production of screen-printed electrodes.
PhD 13	Development of a Plasma Proprotein Convertase Subtilisin Kexin Type 9 (PCK9) Assay as a POCT Predictor of Atherosclerosis	• The PhD was optimising a spontaneously differentiated neuroectodermal progenitor cell (SNEPs) from a human induced pluripotent stem cell. This work was to ensure there were no differences in the expression of genes of interest (PAX1, PAX6, S100B, Nestin) and to ultimately decide on the cell line to use as a reporter system for the PhD's human model.

In addition to the above, the Project Partners notes that (as of July 2019) Artificial Intelligence (AI) training has been delivered to five businesses including PwC, Kainos, BeSecure, axial3D, and Almac.

7.5.3 *Progress towards the Project's stated Objectives*

Table 4.26 provides a summary of the progress that has been made by the project against its stated objectives.

Table 7.25: Project Specific Objectives

Project Specific Objectives	Level of Achievement	Explanation
To create a cross-border centre of research competence and excellence within the field of cardiovascular medicine by March 2017	To a minor degree	The cross-border element of the project was commencing, with the project partners beginning to achieve some cross border publications and collaborations.
To undertake excellent research (commencing at TRL levels of between 1 and 3), through the creation of 24 PhD studentships	To a minor degree	The PhD researchers have started to work on their research projects and the postdocs had started planning out the development of their platform technologies.
To engage with ten industry partners at TRL levels of between 2 and 6.	Not achieved	This has not started yet.

7.5.4 *Progress towards the Project's Output Indictors*

Table 4.27 provides a high-level summary of the progress that has been made by the ECME project towards its Output Indicators (as of July 2019).

Table 7.26: Progress towards the Output Targets (as of July 2019)

Output Indicator Description		Programme Target	Total	Progress	Commentary on prgress
C001 - No. enterprises receiving support		20	**10**	0	Not started
C002 - No. enterprises receiving grants		10	**5**	0	Not started
C004 - No. enterprises receiving non-financial support		20	**10**	5	In progress. Artificial Intelligence (AI) training has been delivered to five businesses including PwC, Kainos, BeSecure, axial3D, and Almac.
C024 - No new researchers in supported entities	T1.8.1		**21**	6.8	Behind schedule
	T2.1.1		**21**	7.2	Behind schedule
	T3.1.1		**21**	7.5	Behind schedule
	T4.1.1		**17**	6.8	Behind schedule
	T5.1.1		**15**	5.3	Behind schedule
	Total FTEs	514	**95**	33.6	Behind schedule
C026 - No. enterprises cooperating with RIs		10	**10**	0	Not started
C041 - No. enterprises participating in cross-border research projects		10	**10**	0	Not started
C042 - No. research institutions participating in cross-border research projects		10	**5**	5	Proceeding according to work plan

7.5.5 *Target Groups Reached*

The Evaluation Team's review of the ECME's LoO and Progress reports indicate that the project was not allocated target group targets.

7.5.6 *Progress towards the Project's Result Indicator Targets*

At July 2029, the ECME project partners report that it has created 4 peer-reviewed journal and conference publications with cross-border authorship, with a further 21 being planned/in progress. The Project Partners have indicated that the target to create 81 cross-border publications will be challenging due to the multi-disciplinary partners engaged in the project.

Table 7.27: Progress towards the Result Indicator Targets

Category	No. of Papers
Joint cross-border papers published	4
Planned Joint cross-border publications	21
Planned publications with no Cross-Border author	38

The four cross-border publications were indicated to be as follows:

Table 7.28: Cross-border publications produced

Title	Type of publication	Target Journal / Conference	Lead Institution
State of play of wearable devices for the measurement of Heart Rate: A systematic review of the accuracy of wrist-worn technologies.	Peer-reviewed Abstract	Scottish Cardiovascular Forum 2019	DKIT
An Unobtrusive Measurement of Upper Extremity Velocity During Post-Stroke Rehabilitation Exercises	Joint Paper	IEEE BHI 2019 Conference	UU
Non-obtrusive Monitoring of Home-Based Post-Stroke Rehabilitation Exercises Using Heterogeneous Sensors	Joint Paper	IEEE BHI 2019 Conference	UU
ST changes observed in short spaced bipolar leads suitable for patch-based monitoring.	Conference Paper	Computing in Cardiology 19	

7.5.7 *Factors that have impacted on the achievement of the Project's Output and Result Indicators and the Priority's Specific Objectives*

The Project Partners advise that the project has only encountered a small number of issues in the delivery of the ECME project to date.

Specific issues identified by the Project Partners include:

- **Delays in the recruitment of PhD students** to support project delivery - Consultation with the Project's Partners indicate that there were delays in the recruitment of PhD students to support the delivery of the ECME project, which may have arisen due to the fact that a number of different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the life and health sciences sector. This inadvertently created significant demand within the market for these students at the same time, resulting in a shortage of available students and, by association, delays in recruitment;

- **Student mobility issues** - Difficulties have been encountered in non-EU resident PhD students travelling outside their country of research residence. Whilst it was noted that the use of videoconferencing has served to mitigate this issue (at least in part), it has not served to facilitate the levels of interaction between PhD students and wider research staff than might otherwise have been the case.

- **Merging of different research disciplines** – The Project Partners note that the ECME project has assembled a research team consisting of 'pure' and social scientists. The Partners note that, on occasions, this has created a challenging work environment and the need to illustrate the respective strengths of each discipline to garner stakeholder buy-in of the role on the project.

- **Difficulties engaging SMEs vis-à-vis large businesses** – The Project Partners note that they have faced difficulties engaging SMEs on the project, potentially due to their relatively lower levels of capacity and capability to engage in substantive R&I. In comparison, such issues have not been faced in engaging with larger businesses.

On a more positive note, the Project Partners highlighted the emergence of Artificial Intelligence within the healthcare sector and are of the view that the project is uniquely positioned to integrate this medium within the project and support businesses that are interested in implementing it within their operations. The lead Project Partner notes that the initial project plan, and businesses targeted therein, may need to be amended/'flexed' to take advantage of this emerging opportunity.

7.6 Best Practice and Learning

Key examples of best practice and learning that have emerged during the initial period of the project's delivery include:

- Delivery of activities to enhance levels of knowledge transfer and PhD student development – The ECME project has delivered a series of activities that have sought to enhance levels of knowledge transfer, PhD student development and longer-term sustainability beyond the project period. Examples of these activities including:

  - Joint training sessions focusing on developing transferable and 'real-world' skills such a resilience, entrepreneurship, presentation and time management skills;
  - 'Match-making' activities and presentations to discuss their research progress, needs and issues;
  - Structured games and challenges to foster teamwork; and
  - Informal social activities.

  Ultimately, the Project Partners are of the view that these wider activities contribute to establishing a 'bottom-up' approach to the research activities and support the creation of potential 'leaders of the future'; and

- Rotation of quarterly progress meetings at each of the Project's Partner's respective institutions to coincide with other events/conference in order stimulate a joint sense of project ownership (rather than the project being UU-centric) and greater levels of transnational interaction;

7.7 Synergies between Projects funded

ECME's management team at Ulster works closely with the co-located SPIRE 2 and Centre for Personalised Medicine staff across common Doctoral College activities including generic training and development of PhDs and in delivering on the Marie Curie principles for research.

ECME's project partners also note that that has undertaken a number of informal meetings with the other INTERREG VA project managers.

7.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the ECME project's collaborative and partnership working including:

- The effectiveness and added value of the ECME project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

The ECME project partners suggest that they are implementing a number of activities to enhance the effectiveness of cross-border collaboration in relation to the specific objectives and new ways of working that would otherwise not be possible in the absence of INTERREG VA. These include:

Joint Development	The design of the project has been agreed and constructed on a cross border basis by a multidisciplinary team of world-renowned scientists and engineers from each of the research institutions within the partnership; in conjunction with business intelligence that was relayed to the lead partner through existing industry networks and contacts. Feedback was also been sought from relevant government bodies e.g. DfE/Invest NI, DoH and DJEI, ECHA, CHIC, Councils and NISP etc.
Joint Implementation (including Staffing)	The project partners suggest that the establishment of ECME has represented the culmination of a sustained shared vision by world-renowned scientists; whilst the inclusion of UHI represents a completely new working relationship for all partners. At a strategic level, a Project Management Board has been set up to oversee the work packages. It meets on a quarterly basis in rotating venues amongst the partners. Membership of this project board is drawn from representation from all partners, as well as two industry representatives and Research Office representatives. An Advisory Board meets annually to review and internationally benchmark the project to ensure that it is being suitably and unbiasedly implemented. At an operational level, up to 24 PhD students and 3 RAs will be appointed within the five project partners. The identified work packages have been selected based on expert input, with the firm belief that these projects will challenge PhD studentships and researchers to deliver world-class research, publications, patents, innovation and to grow a new and dynamic cross-border centre of excellence. Each PhD student has a PhD supervision team and in all cases, a cross-border advisor has been appointed to the panel. Areas of expertise have been matched to complement each other and provide the student with exchange opportunities. From the perspective of the PhD students, the intention is that there will be joint supervision across institutions and/or clinical partners. Industry placements will also be encouraged within companies where appropriate. For example, three PhD placements will be based at Craigavon Hospital but will be primarily line managed by UU. Mobility will also be encouraged between jurisdictions through industrial placements and/or secondments between universities. It is anticipated that a knowledge base will be developed by the central project office which will be shared with industry. This knowledge base is expected to include a database of highlights; publications; conferences; training; IP generation; exchanges; industry/clinical interactions; commercialisation activities, etc. There is also be an intention to attend, as a group, large EU, Asian or US conferences/trade shows to demonstrate the impact of such a large team. Joint publishing in world-class journals and keynotes at International Conferences; Joint- exchanges; Joint Training (Specialist, academic and commercial); Joint Grant Writing; Visiting Professorships; Equipment access etc., will all be the key elements of the project's collaboration.

The ECME project partners consider that considerable added value has been created as a result of the project's cross-border working. In particular, they believe that based as a result of the new cross-border partnership, and in particular, the introduction of their Scottish partner[84], that they will achieve:

1. Improved research performance and capacity on a **cross border basis**, thus improving the prospects of all the partners going higher up the global league tables.
2. Enhanced **knowledge exchange** and relationship building through the flow of staff, students and researchers seeking to avail of best practice in the various laboratories.
3. A **critical mass** across the geographical spread which will add significant FDI and world recognition opportunities.
4. **Multiple jurisdiction collaborations** create challenges; new solutions and novel thinking and this will provide academic; innovation and commercial trade opportunities.
5. A **higher level of competitiveness** locally, nationally and internationally due to the nature of research; the involvement of PhD students (future leaders) and the close collaboration with industry and clinicians.
6. Greater **funding** opportunities. **Economic advantages** due to high levels of expertise, capability and capacity

The project partners note that in the absence of INTERREG VA funding:

- The universities would not have had the available finance to fund the 24 PhD positions; nor would they have been placed on a mobile contract that sees placement with industry and other partners as standard.
- Their engagement with industry would be less. Whilst the universities have a previous history of engaging with industry, the project partners note that this is not their core remit and funding for this type of engagement, whereby a platform is anticipated to be co-designed and shared with industry for commercial exploitation represents a completely new practice for the project partners;
- Similarly, the open approach, which has seen an industry problem informing PhD titles and involves live feedback and tailoring of research focus is new for the project partners.

7.9 Impact on Business and Industry

This section considers the impact of the ECME project on business and industry within the eligible region.

During consultation, the ECME Project Partners indicated that, to date, businesses direct engagement in the project is in its infancy. As such, and given the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

Notwithstanding this, anecdotal feedback from the Project Partners suggests that the project has served to (at least in part):

- Increase levels of businesses' knowledge in the area of AI which has been identified as a growth area within the healthcare sector; and
- Enhance the knowledge and skillsets of a PhD student and, in doing so, prepare them to meet the needs of industry in the future.

[84] It is noted that some of the project partners based in NI and ROI had previously collaborated, but has done so to a much lesser extent in recent years due to a lack of incentives and support for such activity between the jurisdictions.

7.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the ECME project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

7.10.1 EU2020 Objectives

The ECME project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

7.10.2 The Atlantic Strategy

The ECME project does not offer the potential to directly contribute to the aims and objectives of the Atlantic Strategy.

7.10.3 The Horizontal Principals

The ECME project is anticipated to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

<table>
<tr><td>Sustainable Development</td><td>According to the project partners, the project has been developed with a view to sustainable and positive growth of the connected health sector in the eligible region. It is anticipated that the proposed research, which will be fully available on Open Access at the Gold Level, will inspire the world with innovative technologies, products and designs — in order to enrich peoples' lives while contributing to a socially responsible future. The project design facilitates meaningful engagement between academia and industry, with the following sustainable design considerations:

According to the project partners, the anticipated impact of the project can be considered under the following three headings:

<table>
<tr><th>Environmental</th><th>Social</th><th>Economic</th></tr>
<tr><td>• Effective and more sustainable use of scarce resources
• Sustainable solutions resulting in reduced carbon emissions/pollution.</td><td>• Improved relationships between academia and industry
• Better information on issues relating to cardiology;
• Healthier citizens</td><td>• Improved international standing of the area with the potential to attract new FDI to the area
• Sustainable solutions resulting in a cost-effective approach to health care management by the government.
• New product platforms
• Reduced OPEX costs
• Jobs created/safeguarded.</td></tr>
</table>

The project is working towards a positive impact as moving healthcare management to the home will save on travel and hospital heating costs.

The project also uses zoom meetings where possible to reduce the amount of travel required by project staff and also encourages lift sharing and sustainable transport.</td></tr>
<tr><td>Equal opportunities and non-discrimination</td><td>Ulster University has an Equality Scheme 2012-2017 which sets out the University's commitment to and proposals for fulfilling statutory obligations in relation to Section 75 and Schedule 9 of the NI Act (1998).

Ulster University, as lead partner, has sought to ensure that each of the partners working on the project has provided equality of opportunity during the management and implementation of the project.</td></tr>
</table>

	The project partners citer an example of this whereby they have provided assistance to one of their deaf PhD researchers and encouraged her to present her findings along with the other researchers.
Equality between men and women	Ulster University, as lead partner, has sought to ensure that each of the partners working on the project has adhered to the principles of the Athena Swan Charter[85] are promoted across the partnership. Ulster has received a bronze award[86] in the Athena Swan Charter in 2014. UHI is an Athena Swan member working towards Bronze and recently all Irish Universities and third-level institutions have announced that they are working to address gender imbalances in the higher education sector through the extension of the Athena SWAN Charter to Ireland.

7.10.4 *Contribution to Other Strategies*

The ECME project's activities and objectives align with a number of regional and national action plans and strategies, including:

Table 7.29: Project's alignment with regional and national action plans and strategies

Subject	**Relevant Documentation and Alignment**
Economic	• The ECME Centre Project aligns with the strategic objectives of the Northern Ireland Economic Strategy that sets out the NI Executive's plan to grow a prosperous economy by stimulating innovation by 2020 and it also describes how R&D will position NI as a global innovation leader to build a sustainable economy. • NI's Draft PfG 2016-2021 also aims to modernise health and social care. • ROI's NRP 2016: which recognises Health/labour markets as a source of economic growth and health outcomes. • Similarly, ECME is consistent with Scotland's Economic Strategy 2015 which seeks to foster a culture of innovation by supporting high impact, world-class research in Scotland's universities and improve levels of commercialisation of academic research.
Research and Innovation	• NI's MATRIX Panel which highlights the industry's demand for PhD trained students. • NI's Healthcare Strategy for R&D (2016) also provides a focus on innovation and R&D. • ROI's Innovation 2020 highlights Connected Health and Independent Living as priority areas, focusing on a science and tech roadmap that calls for investment in education and facilities to grow R&D. • ROI's NRP also identified R&D as a means to address unmet healthcare needs. • Scotland's "Smarter Scotland" recognises the country's strong research base and the need to maximise its contribution to the economy.
Health	• Within NI, key reports such as Donaldson and Transforming Your Care, highlight the need for ICT and digital tech to revolutionise healthcare to improve patient and economic benefits. In addition, Quality 2020 refers to integrated care benefits and improved data-driven decision-making to raise the quality of care and outcomes. NI's Healthcare Strategy for R&D also recognises the need to maximise the use of tech and to incentivise innovation. • ROI's 'Future Health' and 'Healthy Ireland' emphasis on chronic illness prevention and shifting from episodic care to outcome-based care. • Within Scotland, key documents include "Achieving Sustainable Quality in Scotland's Healthcare" and "Renewing Scotland's Public Services". These focus on prevention, anticipation and supported self-management. Also developing information technology and business processes to gain from investment in eHealth.
E-health	• In NI, the E-Health and Social Care Strategy is an improvement programme for the HSC, emphasising the need for delivery changes for patients and service users through the use of ICT, tech and data. • ROI's 'eHealth Strategy for Ireland' notes national healthcare ICT spending will be "re-aligned" so that it reaches the "EU average of 2-3%" from the current 0.85%.

[85] This Charter recognizes and celebrates good employment practice for women working in science, technology, engineering and maths (STEM) in higher education and research
[86] The Bronze Award submission includes a three-year Action Plan aimed at supporting and developing the careers of women in STEM at Ulster

Table 7.29: Project's alignment with regional and national action plans and strategies	
Subject	**Relevant Documentation and Alignment**
	• Scotland's eHealth Strategy identifies a number of strategic objectives including supporting people to communicate with NHSS; contributing to care integration; enhancing the availability and mgt.
Cardiology	• NI's Chest, Heart and Stroke's priorities for funding include research into the prevention, treatment, rehabilitation and care. Aligned to the priorities, NICHS is funding research for the study of people and populations. • ROI's Changing Cardiovascular Health highlights a potential epidemic of heart failure over the next 10 years. There is a call for care-led community teams to improve patient outcomes and release hospital capacity. • Scotland's Heart Disease Improvement Plan sets out an ambitious person-centred plan to deliver clinically effective and safe HSC. Inter alia, the plan prioritises the prevention of CVD and heart failure.

In summary, the Evaluation Team is of the view that the ECME project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

7.11 Barriers to Cross-Border Cooperation

This section considers whether the ECME project has encountered any barriers to cross-border cooperation that the priority axis is not addressing.

The ECME project partners note that an issue that they have encountered has been the differing policies in place with regards to PhD training. To address this, they allowed flexibility to ensure that the training procedures employed meet both institutional and project requirements. No further barriers were cited by Project Partners.

7.12 Exit Strategy

The ECME project partners note that the project's research area is known to be successful (high economic impact, high-quality outputs and recognised for training) and well-aligned with global challenges, government policy and industry needs. Therefore, the project's sustainability is a key aspiration of the partnership. The project partners indicate that they will seek to ensure the future sustainability of the project through implementation of the following activities:

- Implement an 'Innovation Plan' to address all potential routes to success; funding and economic benefits.
- Secure additional funding to sustain the collaboration e.g. EU; US-Irl; UKRC; SFI; Enterprise etc.

8. BREATH - BORDER AND REGIONS AIRWAYS TRAINING HUB

8.1 Introduction

This section of the report considers the BREATH (**B**order and **RE**gions **A**irways **T**raining **H**ub) project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry-relevant research and innovation capacity across the region.

8.2 Project Overview

Chronic Obstructive Pulmonary Disease (COPD) is an incurable and slowly progressive lung condition characterised by progressive airflow reduction, breathing difficulties and irreversible lung damage (emphysema). Because it is often unrecognised and undiagnosed COPD is sometimes called the 'invisible' lung disease, yet it impairs quality of life with great attendant social and economic costs and, ranks as the 3rd leading cause of death worldwide (Global Burden of Disease (GBD) Study 2010). An estimated 3.2 million adults in the UK have COPD but 70% (2.1 million) go undiagnosed[87]. It is highly prevalent in the border regions of Ireland and Western Scotland, with it suggested that COPD will be responsible for one-third of deaths by 2020.

COPD is also associated with inequality and social deprivation as evidenced by the fact that there is a 200% difference in Irish COPD death rates between the lowest and highest occupational groups[88]. The INTERREG VA Eligible Region has been identified as an area of social deprivation that suffers from a lack of economic competitiveness, high unemployment and comparatively poor living conditions and consequently relatively poor health and lowers life expectancy. Indeed, Ireland (North and South), together with Scotland, bear the unfortunate distinction of being amongst the world's leading countries in terms of its prevalence. For example, Ireland ranks highest amongst the Organisation for Economic Co-operation and Development (OECD) member countries for COPD-related hospital admission rates. Similarly, the risk of COPD-related hospital admission in Ayrshire and Dumfries and Galloway is amongst the highest in the UK, with notable 'hot spots' also occurring throughout NI, particularly in Belfast, Derry and the border areas of Fermanagh, Tyrone and Armagh.

COPD also imposes a huge economic burden on the Region, not only on health services but also in terms of its wider economic impact. A recent report[89] noted that *"In Ireland in 2012, for those prescribed medication consistent with a diagnosis of COPD, the drug cost to the State under the drug schemes was almost €650 million. These costs did not include additional drugs such as antibiotics, nor long term oxygen therapy, supply of nebulisers or vaccines, nor did it include GP costs or costs of care in the community.*

Of the Irish Health sector budget in 2011, €3bn was spent on admissions in the acute hospital sector. Admissions with a primary diagnosis of COPD accounted for 3% of this budget (€91.2m or 4.26% of inpatient, 0.87% of day case budget). Admissions with a primary or secondary diagnosis of COPD accounted for 8.2% of the budget (€248.2m or 12.12% of inpatient, 1.51% of day case budget).

The estimated annual economic burden of COPD in the EU in 2011 was €141.4bn. As this excluded the undiagnosed, those with mild disease and those with COPD co-morbidities, it is an underestimation of the true cost. The figures for Ireland are likely to be at least in line with this or higher, given the probable high prevalence and relatively high hospitalisation rates compared with European counterparts.

COPD places a huge burden on individuals, families and society in terms of disability and premature mortality, indirect health service costs and the indirect costs related to disability, premature death and lost production".

[87] Source: An Outcomes Strategy for COPD and Asthma, Companion Document NHS.
[88] National Respiratory (COPD) Framework 2008
[89] Chronic Obstructive Pulmonary Disease (COPD), Royal College of Physicians of Ireland, 2014

Similarly, in Scotland, COPD is the only major cause of death on the increase. There are thought to be about 100,000 people in Scotland living with COPD, with a predicted increase of 33% in the next 20 years. It accounts for over 122,000 bed days and 4,500 deaths every year. Audit Scotland estimates that the direct cost of COPD to NHS Scotland is £100m per year.

COPD is therefore under-recognised and undertreated, hence there is a real need for impact in terms of prevention, treatment and management.

The BREATH (**B**order and **RE**gions **A**irways **T**raining **H**ub) project is an ambitious, collaborative research Partnership that is seeking to harness the complementary resources and expertise of 10 Principal Investigators (PIs) from Dundalk Institute of Technology (DkIT), Queen's University Belfast (QUB) and University of the West of Scotland (UWS) with a mission *"to establish a cross-border research hub for the development of innovative approaches to tackle COPD by identifying new targets and treatments, establishing an interregional PhD training network and fostering industry-linked research capacity in the Eligible Region".*

To this end, the project partners have proposed to develop an innovative, industry-relevant training programme to stimulate R&I, attract inward investment and enhance economic development in the Region.

The project combines the project partners' expertise in airway smooth muscle (DkIT), epithelial and neuronal function (QUB) and inflammation (UWS) that is considered to be required to develop novel early diagnostic tests and treatments for COPD. It is anticipated that QUB clinicians will ensure that BREATH research is patient-focused. The project partners consider that the strength of BREATH will be to draw together cross-regional expertise in airways cell biology, biomarker discovery and inflammation providing a hitherto unavailable opportunity to develop innovative new skills and models related to COPD.

The need for the project has been informed by the project partners' consultations with medical experts, patient groups, government depts/policymakers, politicians and industry. Indeed, according to the project partners, despite the high prevalence of COPD and the associated mortality and morbidity within the Region, there has been almost no research or training provision in this field. They suggest that this is in stark contrast to other lung diseases such as asthma, cystic fibrosis, lung cancer and Acute Lung Injury where significant progress in developing training structures and advancing early drug discovery has been made.

The project partners have provided the following description of 4 distinct areas of need that have been identified, the objectives that they have set to address the need, and the actions that they will undertake to achieve the objectives:

Table 8.1: Four distinct areas of need			
Need Identified	**Who is affected (and anticipated Beneficiaries)**	**Associated Objectives**	**Proposed BREATH Actions**
Within the region, there is high COPD incidence and great attendant social and economic cost.	Patients, families, employers, Health Services.	1. Identify novel diagnostics and therapeutic targets to treat COPD	The BREATH project's proposed scientific research and training will address the causes, treatment and prevention of COPD by combining the multidisciplinary expertise and existing facilities of the 3 Partners across the Region. By locating BREATH within a Region of high COPD prevalence, the project partners will have access to human tissue samples and to patients for clinical studies. BREATH will: • Develop **innovative approaches to target new treatments for COPD** by integrating multidisciplinary expertise and promote collaboration with industry to create transformative change in COPD research on a cross-border and interregional basis. It is anticipated that projects will be performed on a collaborative basis involving co-supervision of each PhD by a PI from a Partner institution and at least 1 exchange to a Partner lab to learn new techniques and broaden project scope; • Create **transformative change in COPD research** by establishing a sustainable regional hub of applied research excellence combining clinical, academic and industrial resources and expertise across the Region; • **Raise public awareness of COPD** and target susceptible communities to reduce key risk factors (e.g. smoking) and promote health and wellbeing in the Region. This will be achieved by: − Active promotion of BREATH activities and outputs - through social media, press and event attendance e.g. Science festivals and conferences; − Interaction with COPD patients to shape BREATH research to patient needs through liaison with local charities and patient advocacy groups to include invited talks at patient support groups (Chest, Heart and Stroke; British Lung Foundation); − Enthusing students on the benefits of science and technology and the potential to transform society - STEM events; − Promotion of health and wellbeing in the Region - Respiratory Health Days at selected schools (to include lung function assessments) to educate children on the risks of smoking and annual poster competitions. The project partners note that progress will be measured by the number of scientific publications, conference presentations and invention disclosures lodged with Technology Transfer Offices by 2023.

Table 8.1: Four distinct areas of need			
Need Identified	**Who is affected (and anticipated Beneficiaries)**	**Associated Objectives**	**Proposed BREATH Actions**
The economies of the Region have a low proportion of high-value sectors and have low levels of R&I.	Regional communities, workers, graduates, SMEs	2. Increase R&I across the Region by providing world-class training to the next generation of researchers.	The BREATH project partners recognise that the 'availability of talent is a key differentiator for winning FDI' (*Innovation2020, DJEI*). However, the Region has suffered from a dearth of investment from high-value sectors including pharma and biotech industries. To this end, BREATH intends to provide a pool of world-class scientists with an array of scientific, interpersonal and innovation skills matched to the needs of pharma and technology companies, healthcare, education and the wider business community. At the outset it was anticipated that BREATH would train 22 world-class scientists in an array of scientific, interpersonal and innovation skills in demand by pharma and technology companies, healthcare, education and wider business community by 2021, comprised as follows: • 16 PhDs (6 DkIT, 6 QUB, 4 UWS), appointed to undertake cross-border or interregional research projects over 4 years • 5 Post-Doctoral Research Fellows (PDRFs - 3 DkIT, 1 QUB, 1 UWS)), appointed for 4.5 years; • 1 Clinical Fellow (Project Co-Ordinator, QUB), appointed for 3 years. The project partners indicate that the infrastructure and expertise needed for excellent research training already exists within the partnership. However, BREATH will upscale this to create a world-class training network to **maximise career prospects and employability** of researchers in line with the Charter and Code for Researchers. The project partners will utilise their expertise and specialist resources to provide PhDs and PDRFs with a unique blend of transferable and complementary non-scientific skills, including leadership, innovation and entrepreneurship, IP protection, technology transfer and marketing, business strategy/planning, negotiation and regulatory affairs. The training will be conducted on a cross-border and interregional basis. The BREATH PhD students will receive project-specific technical training in their host institution and Partner lab to include workshops, lectures and journal clubs. Further development of their scientific, transferable and business skills will be achieved by attending **Training Events (TE)** which will be monitored, and quality assured by the Scientific Supervisory Board (SSB). Each PhD will also participate in the BREATH Public Engagement and Outreach programme. Scientific outputs and PhD progress will be monitored annually by the Scientific Supervisory Board.

Table 8.1: Four distinct areas of need			
Need Identified	**Who is affected (and anticipated Beneficiaries)**	**Associated Objectives**	**Proposed BREATH Actions**
There is no effective cross-border partnership that significantly impacts on the overall regional capacity for R&I in Health and Life Sciences.	Universities IOTs, Employers, Graduates and SMEs.	3. Develop an innovative **cross-border, inter-regional research hub** focused on the unmet need of COPD	BREATH will bring together 10 Principal Investigators (PIs) from 3 Partner Institutions (DkIT, QUB and UWS) located in the Region. It is anticipated that this connected excellence will significantly enhance the overall capacity for research and innovation in Health and Life sciences in the Region by: • Forming 16 collaborative partnerships; • Sharing expertise in training and research and maximising use of existing facilities. • PhDs will be co-supervised by Partner PIs, maximising knowledge transfer across BREATH. Lab secondments, joint publications enterprise engagement and access to patient cohorts will enable measurement of cross-border and interregional interactions. The project partners envisage that the collaborations created will endure beyond the funding period, ensuring the sustainability of BREATH.
Although research capacity exists within the region, a lack of collaboration across the 3 jurisdictions has prevented the creation of critical mass necessary to achieve stronger market performance and a stronger innovation pipeline.	Universities IOTs, Employers, Graduates, Regional communities, workers and SMEs.	4. Achieve critical mass that will impact upon the Region by combining our complementary clinical, scientific, innovative and industrial skills.	Individually, the BREATH project partners have significant research capacity, demonstrated by excellent track records in postgraduate training, publication in high impact journals, and a proven ability to attract funding (~€20M), and of commercialisation of research (>80 industry contracts, 6 patent applications, spin-out of the biotech company ProAxsis Ltd etc.). It is anticipated that by combining their complementary skills and facilities, the project partners will create a unique interregional R&I hub not otherwise achievable by the single institutions or separate countries. Each of the BREATH PhD projects will run on a cross-border or interregional basis, which is anticipated to enhance the overall Regional capacity for R&I. The impact will be quantified by the number of: • Researchers trained by 2023; • Industry engagements by 2023; and • Collaborative publications by 2023.

In summary, BREATH will focus its research on COPD both to directly address the first area of need identified, but also serve as a vehicle for delivering solutions to the other specific needs identified.

Of note, the project partners advise that the fair principles of IP and joint ownership of collaborative work will be recognised by PIs and researchers, in line with the EU Code of Conduct for Researchers. Co-authorship will be mutually agreed using internationally accepted standards of significant joint contributions in terms of IP, documented effort and authorship.

It is anticipated that BREATH will:

- Engage with (at a minimum) 5 enterprises, through the provision of expert advice and support. At the outset it was anticipated that these businesses would initially include:

ProAxsis (Belfast, NI)	ProAxsis, a spin-out from Queen's University, is a life sciences company focused on the development of a unique range of products for the capture, detection and measurement of active protease biomarkers of disease. Their rapid and easy-to-use tests incorporate patented "ProteaseTags"; smart molecules which trap an active protease within a complex biological sample and enable a visual readout of its presence. A number of active protease species have been extensively validated as biomarkers of disease activity in areas such as cancer, infection, cardiovascular and respiratory disease. ProAxsis is focusing in the first instance on products to aid the diagnosis and management of chronic airways diseases such as cystic fibrosis and COPD. They launched their first-in-class ProteaseTag activity-based immunoassay kit in July 2015 and are currently developing a Point of Care (POC) test for the routine monitoring of patients. They are working on expanding their product pipeline and are keen to be involved in the BREATH consortium on multiple levels, from post-graduate support (to include placements), provision of novel reagents and in the development of new lab-based or POC activity-based immunoassays. ProteaseTag compounds have been extensively used as research tools in the lab for the detection and characterisation of novel proteases biomarkers. ProteaseTags can also be incorporated into a number of existing technology platforms and have the potential to be refined to suit emerging technologies e.g. bead technologies such as Luminex (Bio-Plex), which has been requested in the equipment budget by QUB. ProAxsis, therefore, feels that there is a strong fit between its aspirations and BREATH's objectives, with funding requested to support the further development of new services and products for COPD research, management and treatment. As proteases are an important feature of ion channel modulation, inflammation and infection in COPD, ProAxsis has the expertise to develop novel reagents and tests for the detection of relevant protease biomarkers which could prove to have both diagnostic and prognostic value in COPD. In addition, it is anticipated that these tools will be useful for the post-graduate programme to assay active proteases within a number of experimental models. As a BREATH Partner, ProAxsis will have additional opportunities to build its product pipeline and expand its capacity as a diagnostics company within the respiratory field. BREATH will also provide ProAxsis with opportunities for company promotion and collaboration with other enterprises through networking events such as the BREATH conferences. The proposed timeline for engagement with ProAxsis is as follows: • 2017 - Ongoing provision of novel protease tag compounds to assist BREATH researchers in the evaluation of protease biomarkers of COPD; • 2018 - 2021 - Attendance at BREATH conferences; • 2019 - Identification of novel protease biomarkers will enable the development of activity-dependent immune assays for potential commercialisation. • 2019 - Opportunity for student placement.

Axis Bioservices (Coleraine, NI)	Axis Bioservices Ltd (Axis) provides preclinical services and consultation services in inflammation and oncology to the pharmaceutical industry, including small biotech companies, third level education institutions and larger pharmaceutical companies. Specialising in oncology and recently developing a footprint in inflammation, Axis has developed and carried out many tailored models in these areas to further the development of novel drug candidates. They provide in vivo preclinical services – pharmacokinetics, pharmacodynamics, tolerability, efficacy, and a range of cell biology services to complement these studies. They also offer consultation services on bespoke study design including model development and validation. Axis continually seek to improve their service provision and enlarge their areas of experience and expertise. Axis is eager to learn from and assist in a comprehensive cross-disciplinary approach with BREATH. Funding is requested by Axis Bioservices Ltd to fund the development of a lung infection / COPD experimental animal model for BREATH researchers. It is anticipated that Axis will use these funds to establish and validate the model with reference compounds, utilising the tobacco-induced COPD model with poly (I:C) mice to mimic exacerbations seen in human disease which will be utilised to predict the efficacy of new therapeutics for COPD. In addition, Axis is aiming to provide student placement opportunities over the course of the project with potential job opportunities available in the long-term. The proposed timeline for engagement with Axis Bioservices is as follows: • 2017 - 2018 - Establishment of mouse model; • 2018 - 2021 - Attendance at BREATH conferences; • 2018 - 2019 - Validation of mouse model with known compounds; • 2019 - Opportunity for student placement; • 2020 - Model available for evaluation of BREATH compounds.
Prior PLM Medical (Leitrim, ROI)	Prior PLM Medical is keen to grow the company's expertise in the respiratory field. As such, they feel that the BREATH consortium offers a unique opportunity to do so. It is considered that exposure to the clinical expertise and research facilities that the consortium offers will be very beneficial as such facilities can often be difficult to access for an SME in Co. Leitrim. In addition, it is envisaged that attendance at the proposed BREATH symposia/conferences will be of value to Prior PLM, both from a marketing and an educational perspective. Prior PLM is also open to PhD student and post-doc placements at their facility and feel that, in addition to the technical knowledge exchange, this would enable the student/post-doc to further develop soft skills and experience that will be of considerable value in their future careers whilst giving the company an opportunity to evaluate them with a view to potential future roles. Prior PLM's R&D staff are predominantly from mechanical engineering/physics/ electronics backgrounds, therefore, such placements (or future roles), for students who have knowledge and skills in the areas of physiology, chemistry and biology would be of interest to the company. Exposure to the topic of drug delivery to the airways (e.g. anti-inflammatory drugs) in a laboratory and/or clinical settings is also considered to be particularly attractive to Prior PLM. The proposed timeline for engagement with Prior is as follows: • 2018 - 2021 - Attendance at BREATH conferences; • 2017 - 2019 - Opportunity for student placement.

Raptor Photonics (Larne, NI)	Raptor design and manufacture high-end imaging cameras. DkIT has worked closely with these engineers to develop the world's first commercially available EMCCD camera. Raptor initially targeted the surveillance market but now wish to expand into the biomedical imaging field. It is anticipated that they will utilise the skills and facilities on offer in BREATH (predominantly at DkIT) to test and help develop new high speed, high-resolution EMCCDs for the biomedical imaging market. Consequently, from the very start of the BREATH programme, DkIT will obtain prototype cameras from Raptor and bench test these against their competitors. The PIs in DkIT will, as they have done in the past, provide feedback to the company to assess the sensitivity, spatial and temporal resolution of these cameras so that they are optimised for live-cell imaging. DkIT envisages that Raptor will produce a series of cameras, based on different EMCCD sensors over the course of the BREATH project and DkIT will rigorously test these for live-cell imaging applications. This will not only benefit Raptor but will provide BREATH researchers with the capability to study airway cell function in detailed fashion using the latest technology prior to its commercial release. Whilst the details of these cameras are commercially sensitive and DkIT cannot list the precise specifications or timelines for their production, they consider, based on their previous experience with camera development, that over the course of the 5 years, if the prototype performs to expectations, to test at least 1 camera configuration per year. Consequently, if the camera manufacture and assembly occurs within the proposed production timelines, DkIT would expect their timelines for engagement with Raptor to follow as below. NB This timeline is dependent on camera development and its performance under laboratory conditions. • 2017 - Prototype camera supplied by Raptor for initial testing by DkIT; • 2018 - 2021 - Attendance at BREATH conferences; • 2018 - Feedback and on-camera performance provided by DkIT; • 2019 - Refinement of Raptor Camera prior to camera launch; • 2020 - Raptor EMCCD for biological imaging launched.
Norbrook Laboratories (Newry, NI)	In advance of its application, DkIT had been in discussions with Norbrook Laboratories about the potential application of its novel ion channel modulators to the veterinary medicine market. In addition, DkIT outlined a potential strategy for developing these compounds for the veterinary market. As a result, Norbrook expressed interest in a potential application of the compounds as novel anthelmintics. Based on DkIT's previous work with Biopharma companies, it is envisaged that this project will involve the DkIT PIs developing their assays to screen for anthelmintic activity and demonstrating that their compounds can adversely affect parasite motility. The first assay involves the use of the model organism, C.elegans, to measure the efficacy of different compounds on their motility. The second assay, which DkIT hopes to develop, as a contract research service to Norbrook, involves DkIT cloning out a specific ion channel (the large-conductance Ca2+ activated potassium (BK) channel) from specific parasitic worms. DkIT's hypothesis is that subtle structural differences in the BK channels of humans and parasitic worms will permit them to selectively target parasitic worms. With the help of the Technology Transfer Manager (TTM) in DkIT, DkIT aims to continue to engage with Norbrook to avail of any collaborative opportunities. DkIT envisages that Norbrook may: i. License compounds from DkIT; ii. Provide funding to run motility assays with their proprietary compound; iii. Engage DkIT to develop a nematode BK channel assay. The proposed timeline for engagement with Norbrook is as follows: • 2017-2021 - Annual meetings between TTM, BREATH PIs and Norbrook team to discuss (i) potential collaborations and (ii) how PhD training might be further tailored to industry needs. • 2018 - If previous discussions confirm interest in BREATH assays and DkIT's ion channel modulator compounds, the TTM will draw up Contract Research Agreements or negotiate licensing agreements.

- It is anticipated that two of the five enterprises will also receive financial support[90]. These businesses will partner with BREATH and will contribute to work packages for which they will receive financial support (a total of €250,000 over the 5 years (€125,000 per company; De minimus and State Aid rules applying). The remaining enterprises will collaborate with BREATH to avail of the expertise and facilities of the BREATH Partners as specified.
- Train 22 new dynamic researchers: 16 PhDs, 5 Post-Doctoral Research Fellows and 1 Clinical Fellow, providing a total of 89.5 full-time researcher years, as follows:

  - DkIT: 37.5 researcher years (RY) comprising 6 PhDs (24 researcher years) and 3 PDRFs (13.5 researcher years);
  - QUB: 31.5 RY comprising 6 PhDs (24 researcher years), 1 PDRF (4.5 researcher years) and 1 CF (3 researcher years);
  - UWS: 20.5 RY comprising 4 PhDs (16 researcher years) and 1 PDRF (4.5 researcher years).

- Generate 33 peer-reviewed publications (Open Access Green level as a minimum) with cross-border authorship and a further 15 peer-reviewed publications with interregional authorship, suggested to be broken down as follows:

  - 11 international peer-reviewed journal publications with cross-border authorship (ROI and UK);
  - 5 international peer-reviewed journal publications with interregional authorship (NI and Scotland);
  - 22 peer-reviewed conference publications with cross-border authorship (ROI and UK);
  - 10 peer-reviewed conference publications with interregional authorship (NI and Scotland).

  These totals have been broken down for each Partner Institution as follows:

  - DkIT: 6 peer-reviewed papers and 12 conference papers by 2023;
  - QUB: 6 peer-reviewed papers and 12 conference papers by 2023;
  - UWS: 4 peer-reviewed papers and 8 conference papers by 2023.

The BREATH management structure comprises:

- Management Board, responsible for overall management;
- Finance Committee;
- Scientific Supervisory Board responsible for recruitment and progress monitoring;
- External Advisory Committee to inform and advise on cross-border and interregional business development.

Four work plans have been developed.

Table 8.2: Summary of BREATH Project Work Plans (Per Progress Reports)
1. Management (management)
2. Scientific Research Projects
3. Technology Transfer Activities
4. Communication.

[90] The following is proposed: Cross-border projects to include DkIT-Axis Bioservices, transnational projects to include QUB-ProAxsis and QUB-Axis Bioservices and interregional to include UWS-ProAxsis and UWS-Axis Bioservices.

8.3 Project Budget

The BREATH project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €7,734,796.64 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,515,073.09.

However, this was later amended (LoO dated 21st June 2017)[91] offering a grant of up to a maximum of €7,727,271.20 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,506,928.97, as summarised in the tables below:

Table 8.3: Anticipated Project Costs

Summary Budget	Total Project Costs (€)
Staff Costs	2,911,068.48
Office and Administration Costs	1,651,385.80
External Expertise and Services	3,229,617.17
Travel and Accommodation Costs	233,398.64
Equipment Costs	481,458.88
Total	**8,506,928.97**

Table 8.4: Anticipated Project Funding

Funding Sources	Total Value (€) (Public)
Cash Contribution (Partner Supplied/other grant)	779,657.77
Government Match Funding	946,205.99
ERDF	6,781,065.21
Total Grant Funding	**7,727,271.20**
Total Project Costs	**8,506,928.97**
Intervention rate (% ERDF)	80%

8.4 Anticipated Project Objectives, Outputs and Results

8.4.1 Objectives

The BREATH project objectives are as follows:

Table 8.5: BREATH Project Objectives

1. Identify novel diagnostics and therapeutic targets to treat COPD;
2. Increase R&I across the Region by providing world-class training to the next generation of researchers;
3. Develop an innovative **cross-border, inter-regional research hub** focused on the unmet need of COPD
4. Achieve critical mass that will impact upon the Region by combining our complementary clinical, scientific, innovative and industrial skills.

[91] Following identification of an error in the figures approved for the office and administration budget.

8.4.2 Outputs

It was anticipated that BREATH will contribute to each of the output indicators stated for Thematic Objective 1 call of INTERREG VA as detailed below in Table 8.6.

Table 8.6: BREATH's Suggested Output Indicators

Output Indicator	Description	Programme Target	Anticipated BREATH Contribution	BREATH's % of Total	Notes
CO01	No. of enterprises receiving support	20	5	25	It is proposed that BREATH will engage with five enterprises as a minimum.
CO02	No. of enterprises receiving grants	10	2	20%	Two enterprises will receive grants in relation to BREATH: 1. BREATH will have a collaborative partnership with **ProAxsis Ltd**, Belfast. ProAxsis will be actively involved in BREATH and will develop unique research tools that will support the post-graduate programme with the aim of identifying novel biomarkers and/or therapeutic targets for COPD for subsequent commercialisation. 2. BREATH will collaborate with **Axis Bioservices** in a programme to expand their preclinical testing facilities to include respiratory models of disease.
CO04	No. of enterprises receiving non-financial support	20	5	25%	BREATH will provide expert advice and research support (non-financial) to five enterprises: 1. DkIT has a proven track record of working with camera development companies to expand into the scientific and biological market. DkIT will work with **Raptor Photonics** new camera technologies to assess their applicability to live-cell imaging and mucociliary beat measurements. 2. DkIT has initiated discussions with **Norbrook** about the application of DkIT ion channel modulators in the veterinary therapeutics market. 3. **ProAxsis** is a spin-out company from the School of Pharmacy, QUB founded in 2013. It plans to move into new laboratory space in the Northern Ireland Science Park in June 2016 but will require access to specialist equipment and expert advice from QUB for the foreseeable future. 4. **Axis Bioservices** is seeking to expand its preclinical testing to include models of respiratory disease. BREATH will provide expert advice in this area. 5. **Prior PLM Medical** has been intensely involved in the development of respiratory devices for COPD. They have extensive knowledge of the challenges in delivering these products to the market. They will avail of expert scientific and clinical knowledge available through BREATH.

Table 8.6: BREATH's Suggested Output Indicators

Output Indicator	Description	Programme Target	Anticipated BREATH Contribution	BREATH's % of Total	Notes
CO24	FTE Years of PhD (or above) level research	514	89.5	17.4%	BREATH will provide a total of 89.5 full-time researcher years. Figures based on: • 16 full-time PhD students (6 DKIT, 6 QUB, 4 UWS) on cross-border or interregional research projects over 4 years; • 5 Postdoctoral Research Fellows (3 DKIT, 1 QUB, 1 UWS) for 4.5 years; • 1 Clinical Fellow (QUB) over 3 years.
CO26	No. of enterprises cooperating with research institutions	10	5	50%	Five enterprises will cooperate with BREATH as detailed above.
CO41	No. of enterprises participating in cross-border, transnational or inter-regional research projects	10	2	20%	Cross-border projects are proposed to include DkIT-Axis Bioservices; transnational are QUB-ProAxsis and QUB-Axis Bioservices and interregional are UWS-ProAxsis and UWS-Axis Bioservices.
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	3	60%	The BREATH Principal Investigators are located in DkIT, QUB, UWS. Therefore, it is anticipated that BREATH will contribute three research institutions, accounting for 60% of the Programme target. The R&I projects are designed so that each PDRF and PhD student work-plan activity is completed on a cross-border and/or interregional basis (including secondments and supervision in collaborating laboratories).

It should be noted that the actual profile of businesses receiving support through the BREATH project ultimately changed from that anticipated at the outset. The reasons for the changes in the profile of businesses are detailed in the succeeding sub-sections.

The project partners have proposed to achieve the following outputs:

Table 8.7: Anticipated Researcher Numbers and Researcher Years						
	DkIT		QUB		UWS	
	Researchers	Research Years	Researchers	Research Years	Researchers	Research Years
PhDs	6	24	6	24	4	16
PDRFs	3	13.5	1	4.5	1	4.5
Clinical Fellow			1	3		
Total		**37.5**		**31.5**		**20.5**
Grand Total	**89.5**					

Table 8.8: Other Anticipated Outputs				
Anticipated Outputs	**DkIT**	**QUB**	**UWS**	**Total**
Peer-reviewed papers	6[92]	6[93]	4	**16**
Conference papers (Minimum)	12	12	8	**32**
Co-supervised PhDs	6	6	4	**16**
Dedicated TTM	0.21 FTE			**0.21 FTE**

8.4.3 Results

The project partners have proposed the following results for the BREATH project.

- **33 peer-reviewed publications** with cross-border authorship and a further **15** with interregional authorship (thus contributing to the 2023 target result indicator of 75 peer-reviewed journal and conference publications with cross-border contributions). This will comprise a minimum of:

  - 11 international peer-reviewed journal publications with cross-border authorship (ROI and UK);
  - 5 international peer-reviewed journal publications with interregional authorship (NI and Scotland);
  - 22 peer-reviewed conference publications with cross-border authorship (ROI and UK); and
  - 10 peer-reviewed conference publications with interregional authorship (NI and Scotland).

  The project partners intend to target the highest-ranked journals, including Am J Respiratory and Critical Care Medicine, Lancet, Thorax, Nature, Cell, Science and Proceedings of the National Academy of Science (PNAS, USA). It is anticipated that articles will be published by either "green" or "gold" open access (a budget has been included for high impact papers to have full "gold" status).

- **Peer Conference Publications** (included above) – A minimum of **32** oral and poster presentations will be delivered at national and international conferences identified by Principal Investigators (Pis).

It is anticipated that these high-profile publications and conference presentations will enhance the visibility of BREATH research, showcase its work to potential future employers, industry partners and investors and help attract potential investors from pharma and biotech industries to the Region.

[92] Suggested for DkIT to be at a minimum of Open Access Green level
[93] Suggested for QUB, to be published, open access.

8.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the BREATH project's key achievements (as of December 2017[94]) and the extent to which the BREATH project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

8.5.1 *Key Achievements (to December 2017)*

The BREATH project has encountered some factors that have impacted negatively (and perhaps positively), on the project's ability to contribute to the achievement of the Specific Objective on the basis originally proposed.

- Unfortunately, during late 2018, one of the five enterprises (AxisBioservices) that were originally anticipated to participate withdrew from the project[95] due to concerns in relation to the claims process which were deemed by the business to be intrusive, overly bureaucratic, time-consuming and didn't permit the business to utilise pre-existing suppliers. Indeed, the project partners note that one of the project's other businesses Raptor Photonics, and a further prospective business (Fusion Antibodies) indicated that they did not want to avail of grant funding for similar reasons;
- QUB has noted that it was, unfortunately, unable to appoint a clinical fellow despite extensive efforts to attract appropriately qualified people to this position. According to QUB, this was due to a number of reasons, not least the pressures that are currently within Medicine to bring clinical trainees through to clinical appointment as quickly as possible. As an alternative, QUB agreed with SEUPB that it be allowed to recruit an experienced PDRF post, suggesting that there would be no detriment to the outputs of the project in terms of researcher years and opportunities for conference presentations and cross-border publications. Thus, whilst the profile of research staff has been amended from that anticipated at the outset the total quantum of research staff has actually increased (discussed further in Table 8.11); and
- However, in hindsight, QUB suggests that this amendment represented an opportunity rather than a problem. A clinical fellow (CF) was initially requested due to QUB's wish to include a medic in the training of its next generation of COPD researchers. However, it would have been necessary for them to have come into the project as a PhD student requiring training in research skills and techniques. The QUB clinical lead also felt, at the time of application, that a CF would also be able to provide further support in the collection of clinical samples to QUB and the BREATH cross-border partners. This has, however, been mitigated by QUB clinical lead who engaged extensively with respiratory physicians in the Ayrshire and Dumfries and Galloway regions. They were then included as co-investigators in an application to the Office for Research Ethics which has since been approved and is currently at the final stages of research governance within the NHS. This foresight has allowed the University of the West of Scotland to receive clinical samples from hospitals within their own region and in doing so enabled additional engagement with their local NHS and has offered the opportunity for COPD patients in the eligible region to be involved in the clinical aspects of the BREATH project.

[94] Please note that the key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing. It is understood that the project's period 5 - 7 reports are awaiting verification (as of May 2019). Where provided additional detail has been included from the consultation process.
[95] It is understood that as of May 2019, the project partners have yet to submit a change request relating to this business.

Despite these setbacks, the BREATH Project Partners cite the following key achievements:

- They successfully recruited for all proposed research posts;
- During February 2018, BREATH was awarded the Asthma / COPD Project of the Year at the 19th Northern Ireland Healthcare Awards held at the Europa Hotel Belfast.
- Two annual conferences were held – during June 2018 and June 2019; and
- Public engagement with schools is well underway, with, for example, the BREATH COPD Research team spending a week (during October 2018) engaging with over 1400+ enthusiastic Dumfries and Galloway school pupils providing guidance about science and lung function/disease (COPD).

Figure 8.1: Centre for Musculoskeletal Science engaging with School Pupils

The project partners note that 18 research projects are all progressing according to schedule, with all of the appointments of the PhDs being made By October 2017. A high-level overview of the research projects being taken forward is detailed in Table 8.9.

Table 8.9: Overview of the BREATH Research projects

Wp number	Institute	Project Title
A.T1.1	DkIT	Role of Kv7 channels in Airway Smooth Muscle contraction
A.T1.2	DkIT	Mechanisms underlying relaxation of airway smooth muscle
A.T1.3	DkIT	Role of TRP channels in Airway Smooth Muscle contraction in health and COPD.
A.T1.4	DkIT	Relationship between DEPs, PAR-2 receptors and TRPV4 channels in airway smooth muscle
A.T1.5	DkIT	Tuning the selectivity of novel BK channel openers to target airway epithelium
A.T1.6	DkIT	Targeting Kv7 channels in COPD
A.T1.7	QUB	Modulation of ENaC and mucociliary clearance in COPD
A.T1.8	QUB	Proteases and other inflammatory mediators in COPD
A.T1.9	QUB	Infection, innate defence and COPD
A.T1.10	QUB	TRP channels, neuronal inflammation and chronic cough
A.T1.11	QUB	Airway irritant-induced modulation of neuronal pathways in COPD
A.T1.12	QUB	Infection and airway neuronal dysregulation in COPD
A.T1.13	UWS	Elucidating novel PAR2 roles in COPD[96]
A.T1.14	UWS	Serine proteinases modulating PAR2 and ion channels in COPD
A.T1.15	UWS	Pulmonary ageing in COPD
A.T1.16	UWS	Elucidating the role of PAR2 in bronchial smooth muscle in COPD
UWS matched	UWS	Genetics of COPD
UWS matched	UWS	Developing a multi-species biofilm to study COPD

[96] Please note that a UWS match-funded PhD replaced the original PhD student on the this project.

Progress of these projects are monitored at two levels, i) annually within each Partner Institute, according to the Institute's academic regulations and ii) annually at the June BREATH SSB meeting, attended by all PIs and PDRFs. In addition, further meetings of PIs and PDRFs are held in January each year to monitor the overall scientific progress of the project.

The BREATH project partners also cite the following project achievements (as of December 2017) within their Quarterly Project Progress Reports:

Table 8.10: Key Achievements

Period	Dates	Key Achievements
1	1st January 2017 – 31st March 2017	• LOO signed and various pre-conditions completed. • Management structure in place and the first meeting held. • Advertisements, shortlisting for and interviews of DkIT Post-doctoral research fellows and project co-ordinator candidates took place; • Advertisement of PhD posts and shortlisting of PhD candidates.
2	1st April 2017 – 30th June 2017	• PIs interviewed DkIT PhD students and attended interviews for QUB PhD students in QUB; • PIs attended an SSB and MB meeting in QUB; • PIs attended a Royal Academy of Medicine Ireland (Biomedical Sciences section) conference in Dublin.
3	1st July 2017 – 30th September 2017	<u>Staff Recruitment:</u> • The DkIT BREATH Project Coordinator started, as did the 3 PDRFs for DkIT. Interviews for DkIT PhD students were completed. • In QUB, the PDRF and the Technical Officer started their respective positions. Recruitment for a Finance Officer Grade 5 for QUB was initiated. • The BREATH PhD students attended a "Meet and Greet" session on 27th Sept, prior to formally starting on October 2nd. • In UWS, staff and student recruitment were completed. Appointment of a dedicated UWS-INTERREG Project Administrator and 2 PhD students. <u>Meetings:</u> • The EAC committee was constituted and met for the first time. • All BREATH members attended the European Respiratory Society Meeting in Milan and used the opportunity to run a BREATH Supervisory Board meeting. BREATH PIs met with Henrik Olsson (Senior Principal Scientist from Astra Zeneca) regarding future collaboration on the BREATH project; • T/C meeting took place with QUB and NHS partners in Scotland to enable ethics application for patient tissue access. <u>Public Engagement:</u> • Events included: a Stakeholders' Launch in Dumfries and Galloway and BREATH presentation at the Prestwick Aerospace STEM Week for schools. <u>Enterprise:</u> • DkIT PIs visited Mylan, Dublin Respiratory – Pharmaceutical Company. • Joint meetings of BREATH partners with Tissue Solutions to explore tissue opportunities, and AstraZeneca to identify potential work placements.
4	1st October 2017 – 31st December 2017	<u>Staff Recruitment:</u> • All BREATH PhDs, PDRFs and PIs were in place. • In QUB, a Grade 5 Finance Officer was appointed; <u>Meetings:</u> • All BREATH staff and students from DkIT, QUB and UWS met for the first time; • A BREATH team meeting took place on November 14th and the BREATH Launch Event took place on November 15th. The day was particularly important as the launch was planned to coincide with World COPD Day which seeks to raise awareness and improve COPD care throughout the world. Over one hundred patients, healthcare workers and politicians across

Table 8.10: Key Achievements		
Period	**Dates**	**Key Achievements**
		the UK and Ireland came together to launch the integrated cross-border project at the Ballymascanlon Hotel in Dundalk. • Meeting in QUB with DkIT and BREATH PIs and other clinicians in QUB to discuss clinical interaction, and also to discuss the proposed Outreach Programme; • SEUPB EU Showcase at the European Parliament, (20th-22nd November) which was attended by QUB, DkIT and UWS. The exhibition and reception were considered to be a huge success with multiple opportunities provided for discussions with MEPs from both the UK and Ireland in regard to the importance and value of continuing cross-border funding initiatives such as INTERREG post-BREXIT. The reception was also attended by a number of other dignitaries which included EU Commissioner Corina Creţu along with the Irish Permanent Representative to the EU Ambassador Declan Kelleher and the UK Deputy Permanent Representative to the EU, Katrina Williams; <u>Student Training:</u> • Over this quarter the students attended a number of induction and training events. • The students commenced literature reviews relevant to their individual projects and prepared posters and oral presentations for the BREATH team meeting on the 14th November and Launch event on the 15th November. <u>Public Engagement:</u> • In December, an application was prepared and submitted for Asthma/COPD Project of the Year, NI Healthcare Awards 2018. **NB,** it is noted that during February 2018, BREATH was awarded the Asthma / COPD Project of the Year at the 19th Northern Ireland Healthcare Awards held at the Europa Hotel Belfast.

8.5.2 *Progress towards the BREATH Project's Objectives*

The extent to which the BREATH project partners consider that they have met their stated project objectives, as of July 2019, is discussed below:

Table 8.11: Achievement of Project Objectives (as of July 2019)		
Project Specific Objectives	**Level of Achievement (at July 2019)**	**Explanations**
To identify novel diagnostics and therapeutic targets to treat COPD	To a moderate degree	At July 2019, BREATH project partners note that scientific work is progressing well at DkIT, QUB and UWS, and the PhD students are now midway through their projects. Significant progress has been made, as evidenced by 46 conference presentations and 2 scientific papers and several further papers in preparation. A number of other conference papers are planned for the Irish Thoracic Society in November 2019, in addition to project-specific conference attendance in 2020.
To increase Research and Innovation across the Region by providing world-class training to the next generation of researchers.	To a large degree	To date, a range of training has been provided to PhD students and PDRFs. Examples of training are provided in Section 8.6.
To develop an innovative cross-border, interregional research hub focused on the unmet need of COPD	To a large degree	The BREATH Hub continues to thrive with full cooperativity between partners.
To achieve critical mass that will impact upon the Region by combining our complementary clinical, scientific, innovative and industrial skills	To a large degree	The BREATH hub has been established and is continuing to thrive. The BREATH project has further expanded the platform beyond the original 32 (10 PIs, 6 PDRFs/Clin Fellow, 16 PhD students) to 43, including 3 match-funded PhD students, 3 additional PDRF/RAs, and 6 affiliate PIs.

8.5.3 *Progress towards the Project's Output Indicators*

Table 8.12 provides a high-level summary of the progress that has been made by the BREATH project towards its Output Indicators.

Table 8.12: Extent of Achievement of Project Output Indicator Targets (as of July 2019)						
Output Indicator	**Description**	**Programme Target**	**BREATH target**	**Progress at July 2019**	**Variance against project target**	**Commentary on progress**
CO01: Productive Investment	Number of enterprises receiving support.	20	5	5	-	Proceeding according to Work Plan. Achieved and ongoing. The BREATH project is actively engaged with three companies (ProAxsis, Prior PLM Medical and Raptor Photonics) mentioned in the application to varying degrees and has established relationships with Causeway Sensors and Mylan.
CO02: Productive Investment	Number of enterprises receiving grants	10	2	0	-100%	Not commenced. BREATH has an active Partnership agreement with ProAxsis, who is yet to make a claim, but are anticipated to do so in the near future. The other industrial partner, AxisBioservices, withdrew from the project (for reasons stated previously), and BREATH has an agreement from SEUPB to reallocate grant funding originally earmarked for AxisBioservices to a research contract fund open for tender by alternative companies.
CO04: Productive Investment:	Number of enterprises receiving non-financial support	20	5	5	-	Proceeding according to Work Plan. Achieved and ongoing.
CO24: Research, Innovation:	Number of new researchers in supported entities	514	89.5	39.83	-55%	Proceeding according to Work Plan.
CO26: Research, Innovation:	Number of enterprises cooperating with research institutions	10	5	8	+60%	Proceeding according to Work Plan. Achieved and ongoing. As above, the BREATH project is actively engaged with three companies that were originally identified within the

Table 8.12: Extent of Achievement of Project Output Indicator Targets (as of July 2019)						
Output Indicator	**Description**	**Programme Target**	**BREATH target**	**Progress at July 2019**	**Variance against project target**	**Commentary on progress**
						application (two businesses are no longer involved – Norbrook Laboratories and AxisBioservices) and have had active input and co-operation from 5 additional companies to include SMEs (Causeway Sensors and Fusion Antibodies) and large pharma (Teva, Chiesi and GSK).
CO41: Productive Investment:	Number of enterprises participating in cross-border, transnational or interregional research projects	10	2	1	-50%	Proceeding according to Work Plan. As per CO02.
CO42: Productive Investment:	Number of research institutions participating in cross-border, transnational or interregional research projects.	5	3	3	-	Proceeding according to Work Plan

8.5.4 *Target Groups Reached*

In addition, as of December 2017, the project partners had engaged with a variety of its intended 'target groups', as summarised below:

Table 8.13: Performance Against Target Groups Reached Targets (as of December 2017)				
Target Groups	**Description of Target Group**	**Target Value**	**Target Groups Reached**	**Source of Verification**
Higher education and research	Universities	3	12	UWS had met several targeted staff and integrated them into the BREATH programme (co-supervisors). They had been proposed as BREATH Affiliates.
Education/training centre and schools	Schools	0	0	UWS: Met with DnG Council managers to agree on School engagement plan.
SME	Modelling expertise	5	2	UWS: Met with Ricardo Evidence: Social Media
Other	1) SEUPB, healthcare professionals, academics, patient groups, charities, politicians 2) MEPs 3) Grunenthal: Pharma 4) Patient groups already existing within the regions which provide patient support.	0	6	1) BREATH Launch: Press releases and invites 2) EU Showcase: SEUPB and press releases 3) Visit Grunenthal (9th Nov 2017). 4) UWS: Patient Groups via CHSS Evidence: Social Media

8.5.5 *Progress towards the Project's Result Indicator Targets*

As of July 2019, the BREATH project had produced the following number of peer-reviewed journal and conference publications:

- 21 peer-reviewed publications with cross-border authorship (UK and Ireland) against its target of 33 (64% achieved); and
- 8 peer-reviewed publications with interregional authorship (NI and Ireland) against its target of 15 (53% achieved).

Table 8.14: Progress towards the Results Indicators

Name of Output	Programme Target	BREATH Project Target	At July 2019
Peer-reviewed publications with cross-border authorship	75	33	21
Peer-reviewed publications with interregional authorship	Not identified	15	8

In addition to the figures cited above, the BREATH project partners report that it has presented 18 further national or international conference papers[97]. An overview of the journal ad conference publications is provided in Appendix V.

8.5.6 *Factors that have impacted on the achievement of the Project's Output and Result Indicators and the Priority's Specific Objectives*

The Project Partners advise that the project has only encountered minor issues in the delivery of the BREATH project to date and does not anticipate that these will ultimately have an adverse impact on the overall achievement of the Project's Output and Result indicators and the Priority's Specific Objectives.

Two specific issues identified by the Project Partners include:

- **The claims process adversely impacting on business' engagement -** As noted previously the levels of administration and bureaucracy associated with the claims process has resulted in a business leaving the project and other businesses not willing to receive the financial support that is currently available; and

- **Staff mobility issues** - Difficulties have been encountered in relation to the mobility of overseas students travelling outside their country of research residence. The Project's Partners expressed concern that issues in relation to the free movement of research staff could potentially be exacerbated following the UK's departure from the EU (following 'Brexit').

8.6 Best Practice and Learning

Specific areas of best practice cited by the Project Partners include:

- **Delivery of activities to enhance levels of knowledge transfer and PhD student development –** Training of the PhD and PDRFs is central to BREATH's mission and it is around this activity that all of the other activities revolve. Examples of specific training and engagement events which the project's research staff have benefited from include:

[97] These have not been included in the above table on the basis that they were either not published in a scientific journal, or because they did not meet the criteria of either cross-border or interregional authorship. Additionally, there is one BREATH paper published in the American Journal of Physiology that was excluded because it did not meet the authorship criteria.

- Scientific Technical and Laboratory Training for DkIT PhDs was provided, including workshops on Induction (Research Policies, management of IP, Library Resources, Finance and Student Services, Research Management and Personal Development - Communication, Publishing, commercial exploitation of research and Literature Research on the Web;
- Outreach training provided by Sentinus;
- Statistics and IP training;
- A 2-day training session provided by GSK at their headquarters in London and research facility in Stevenage;
- The Pharmaceutical Industry in Action industry-led training Event facilitated by TEVA UK and NICE;
- Chiesi ENGAGE industry-sponsored event, facilitated by Chiesi Ltd. and Medical Science Liaison;
- PDRF chaired conference presentations by all PhDs and attendance of 'Lab mornings' where students discuss their research project progress;
- PDRF-led training 1 – An overview of the technical capabilities across BREATH;
- PDRF-led training 2 - Guidance for writing scientific papers and theses; and
- All of the PhD students delivered oral presentations and prepared posters under the guidance of their supervisors.

In addition to the above, whilst yet to be implemented, the Project Partners note that the project's research staff will undertake a laboratory secondment to a partnering academic institution in the eligible region as part of the project. Ultimately, It is anticipated that these secondments will support the development of the students' technical and practical skills (e.g. communication and time management).

In addition to receiving ongoing project support from their own academic institution, each PhD student is allocated a supervisor in another area within the eligible region. It is the project partners' view that this aspect of the project supports the cross-pollination of skills and knowledge to both expedite the progress of projects and address project-specific issues that arise, contribute to the wider development of the PhD students. Including addressing any pastoral issues that arise; and

- **BREATH has an extensive public engagement programme** to raise awareness of COPD, involving visits to schools (by the PhD students and PIs), active participation in STEM events such as SciFest and Science Uncovered, engagement with politicians at local and parliamentary level, and with patient groups.

8.7 Synergies between Projects funded

Other than engaging in a number of informal meetings with the other INTERREG VA project managers, the Project Partners indicate that there have been no further synergies between the funded projects.

8.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the BREATH project's collaborative and partnership working including:

- The effectiveness and added value of the BREATH project's cross border collaboration in relation to the specific objectives; and
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

Discussion with the project partners indicates their view that the BREATH project has already (at July 2019) formed a successful collaborative partnership. They note that in anticipation of the INTERREG VA R&I call, exploratory meetings between members of the Smooth Muscle Research Centre (SMRC) in DkIT and members of the Experimental Medicine and Biomolecular Sciences Research Groups in QUB took place in September 2014 to discuss a new cross-border research collaboration. Members of the Institute of Biomedical and Environmental Research at UWS were subsequently approached due to their expertise in inflammation. Feedback was also sought from state agencies, relevant government departments and industry representatives. The outworking of these tentative discussions has been the

BREATH project which has been formed to investigate new treatment and diagnostic targets for COPD, which is highly prevalent within the Eligible Region.

Over the 18 months prior to submission of the Stage 1 application, BREATH Partners:

- Held 5 formal face to face strategy and planning meetings;
- Held a conference with PIs, current PhDs and PDRFs to discuss research complementarity;
- Held 3 teleconferences involving PIs;
- Worked together (DkIT and QUB) in each other's laboratories for 6 days to confirm the synergies possible by establishing the proposed research hub;
- Jointly developed the proposed plan and budget via numerous phone calls and emails.

Subsequently, since receiving funding to implement the project, the BREATH project partners have developed, in their view, a unique interregional research and innovation platform that would not otherwise be achievable within the Region. The project partners consider that the unique mix of skills and experience will add significant value to the quality of the research undertaken and also add value to the training experience of the emerging research talent in the Programme. They note, for example, the anticipated added-value that this cross-border collaboration will bring to each of the project objectives:

Table 8.15: Suggested added value of the BREATH project's cross border collaboration	
Project Objectives	**Suggested added value of the BREATH project's cross border collaboration**
1. To identify novel diagnostics and therapeutic targets to treat COPD	According to the BREATH partners, they provide a wide range of complementary skills, resources and expertise that will dovetail to deliver the outputs of the INTERREG VA Programme: • The SMRC (DkIT) specialises in smooth muscle, a recognised treatment target for COPD. Smooth muscle surrounding the airways in the lungs contracts excessively in COPD, constricting the air passages to the extent that airflow is reduced and breathing becomes difficult. The SMRC has developed novel compounds that potentially reverse this process. • The QUB group includes a respiratory physician and clinical scientists who specialise in airway pathology and treatment. This will provide access to patient samples and a range of molecular and cellular techniques not available in DkIT. QUB has spun out ProAxsis, a start-up company specialising in diagnostics for respiratory disease. • The UWS team are expert in the process of inflammation, an integral part of the pathology of COPD. The project partners suggest that combining the expertise, skills and facilities of the three Partners, will permit them to develop a unique interregional research and innovation platform that would not otherwise be achievable within the Region. The BREATH partners consider that this will add significant value to the quality of the research, enhancing Results and add value to the training experience of the emerging research talent in the Programme.
2. To increase R&I across the region by providing world-class training to the next generation of researchers	Whilst the project partners recognise that it is possible to train new researchers without a cross-border dimension, they suggest that the pooling of talent and resources of all Partners will ensure that training is delivered at a globally competitive level. Furthermore, they consider that the cross-border and interregional collaborations will maximise the combined benefit of the existing capacity and expertise and make each Institution's resources accessible, thereby substantially enhancing the training experience for the new researchers. The BREATH partners further indicate that the project will create an interregional, interdisciplinary, intersectoral PhD programme, where PhD researchers and PDRFs will have experience of working in the different research contexts provided in the Republic of Ireland, Northern Ireland and Scotland and receive outstanding training provided by a cross-border supervisory team.
3. To develop an innovative cross-border, interregional research hub focused on the unmet need of COPD	The project partners consider that as a cross-border project, BREATH will address the unmet need of COPD, by establishing a dynamic, integrated and sustainable research platform to transform the overall regional capacity for research and innovation in Health and Life sciences by increasing collaborations, sharing expertise and maximising the use of existing facilities. They note that each of the project's work-plans has inbuilt cross-border or interregional components, including partner secondments, enterprise engagement and access to patient cohorts across the Eligible Region. It is considered that the secondment of PhD researchers across institutions will cement partnerships, ensure mixing and result in knowledge of other jurisdictions and development of personal networks that will be of continuing benefit after project completion. Ultimately, the project partners suggest that the particular benefit of creating this cross-border network lies in enabling access to a wider pool of expertise across the entire Region.
4. To achieve critical mass that will impact upon the Region by combining the Project Partners' complementary clinical, scientific, innovative and industrial skills	The Partners currently have significant established research capacity. Given this, they consider that co-alignment of BREATH researchers will create critical mass within the Region to enable them to produce globally competitive research that benefits the Region in terms of improved health and economic development. The BREATH partners suggest that the combination of their complementary skills, techniques, experience and facilities within an academic-business-clinical framework will permit them to develop a unique interregional research and innovation platform with a reach and local relevance not otherwise possible. They anticipate that this will ensure that BREATH will impact on the overall Regional capacity for research and innovation. Indeed, the project partners consider that there is potential for the project to become self-sustaining by the end of the Project, through the ongoing development of clinical and industrial links, attracting research income and innovation investment from diverse sources, facilitating an ongoing benefit to the Region.

To facilitate the implementation of the project on a cross-border basis, the project partners note that they have developed a shared vision and project goals and created a shared Management Structure[98], appointed a shared Project Coordinator (PC), and will jointly supervise PhD projects[99], make joint conference presentations, and intend to issue publications on a shared basis. In addition, one of the PDRFs that has been recruited is a Medicinal Chemist, shared between DkIT and QUB.

Ultimately, the project partners suggest that if an effective joint implementation does not occur, the project may not achieve its scientific results. The progress of the PhDs will be monitored by the Scientific Supervisory Board (SSB). The SSB will also be responsible for the delivery of scientific results and outputs and recruitment of researchers.

In addition, an External Advisory Committee (EAC) has been created that includes representatives from the key economic development bodies (Invest NI, IDA and Scottish Enterprise) in each of the three jurisdictions to advise on cross-border and interregional business development.

8.9 Impact on Business and Industry

This section considers the impact of the BREATH project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

However, the Projects Partners are of the view that the BREATH project will significantly increase the capacity for R&I in the region by forming more than 16 new collaborations, sharing expertise in training and research and maximising the use of existing facilities.

8.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the BREATH project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

8.10.1 EU2020 Objectives

The BREATH project continues to offer the potential to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth. The project partners suggest that the project will contribute to the further development of the Regional Knowledge Economy through the development and implementation of 16 individual and bespoke R&I projects.

Furthermore, the BREATH project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

[98] This involves quarterly meetings of the Management Board (MB) to review the progress of the project against its targets. The MB comprises a representative from each Institute and the Project Coordinator, and is responsible for overall management (commercialisation, financial and administrative, including the Partnership Agreement and contract) of the BREATH consortium.
[99] Each PhD student will have a main Supervisor in one site and a co-supervisor in a cross-border or interregional site where they will complete their laboratory secondment (for up to 6 weeks). The progress of the PhDs will be monitored by the Scientific Supervisory Board (SSB).

8.10.2 The Atlantic Strategy

The BREATH project does not offer the potential to directly contribute to the aims and objectives of the 'Atlantic Strategy'.

8.10.3 The Horizontal Principals

The BREATH project partners consider that the project will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

Sustainable development	The BREATH project partners suggest that BREATH will contribute directly to Sustainable Development goals in the following ways: • Enhancing levels of social inclusion, by tackling COPD - a particular and pernicious condition which has a particularly high prevalence in the eligible region, and which prevents many people from participating in economic and social life; • By providing a model of cross-border and inter-regional partnership, working to tackle shared but intractable problems.
Equal opportunities and non-discrimination	Each of the BREATH partners is committed to equality and indicates that they will comply with the legal requirements set out in legal instruments such as Section 75 of the Northern Ireland Act 1998, the Employment Equality Act (1998) and Equal Status Act (2000) (as amended by the Equality Act (2004)) in the Republic of Ireland and the Equality Act 2010 in the United Kingdom (covering Scotland). At an individual level, both Queen's University Belfast (QUB) and Dundalk Institute of Technology (DkIT) hold the HR Excellence in Research Award, demonstrating their dedication to transparent and fair recruitment processes. Similarly, UWS' Equality and Diversity Policy outlines their dedication to promoting and implementing equality of opportunities in teaching-learning, research and working environment. In addition, the Project Partners offers a range of equality and diversity training to all staff and students. The Project Partners note that they have taken, and will continue to take, appropriate measures to ensure that no discrimination occurs/will occur based on sex, racial or ethnic origin, religion or belief, disability, age or sexual orientation during the project's preparation, set-up and implementation. Recruitment to positions created by this research project has been based exclusively on individual candidate's merits and suitability as set against the advertised job descriptions.
Equality between men and women	As noted, each of the Partner institutions has clear policies in place to ensure equality of opportunities and non-discrimination in relation to gender and other aspects of equality. Applications have been screened using eligibility criteria based on Marie Curie rules to ensure transparency and equality of selection. Potentially successful applicants have been shortlisted and invited for an interview to assess their skills, knowledge and relevant research/industrial experience (taking account of career breaks), their capacity and enthusiasm to undertake the training activities and the expected impact on their future career whether in academia or industry. The project partners state that they intend to work with the women leaders in the team to promote full equality of opportunities for women, noting that both QUB and DkIT are signed up to the ECU's Athena SWAN Charter, which was established in 2005 to encourage commitment to advancing the careers of women in science, technology, engineering, maths and medicine (STEMM) employment in higher education and research. They note also that BREATH will ensure the use of gender-neutral language in all documents and will integrate a gender dimension in public outreach actions.

8.10.4 Contribution to Other Strategies

Given BREATH's focus on research, innovation and health, the project partners consider that the project aligns with and has the potential to contribute to:

- EU policy to reduce risk factors associated with chronic diseases such as COPD[100] and also addresses concerns raised by the European COPD Coalition regarding lack of a concerted focus from the EU on chronic diseases (http://www.copdcoalition.eu); and
- A number of specific strategies within each of the three jurisdictions, and in particular those that relate to innovation, economic growth and development and also national health strategies, as discussed below:

Northern Ireland	• **Northern Ireland Programme for Government (2016-2021)** which outlines an aspiration for NI to become *'one of the UK's leading high-growth knowledge-based regions which embraces creativity and innovation at all levels in society'* and identifies *'the key drivers of economic growth as including innovation, R&D and improving the skills and employability of the workforce'*. • **The Northern Ireland: Economic Strategy** which plans to grow a prosperous local economy by: - Stimulating innovation, R&D and creativity to widen and deepen NI's export base; and - Improving the skills and employability of the entire workforce.
Republic of Ireland	• **The Programme for Partnership Government (2016, Ireland)** which states that government will invest in skills and training to *'increase capacity to educate, develop deploy and retain talent and encourage their delivery in partnership with enterprise'*. • **Innovation2020 (Ireland)** which describes how R&D, science and technology will position Ireland as a Global Innovation Leader to help build a sustainable economy by: - Increasing enrolments in Masters and PhDs to meet the growing demand for talent from enterprise; - Undertaking excellent research with relevance and impact for the economy and society; - Developing a strong, innovative and internationally competitive enterprise base; - Maximising exchange of talent and knowledge between Ireland's public research system and industry; - Creating an internationally competitive research system that acts as a magnet and catalyst for talent and industry. • **Healthy Ireland'** which states *'Economic growth improves health, which also significantly enhances economic productivity and growth'*. • Furthermore, a **COPD Position Paper** (Royal College of Physicians of Ireland, 2014) which states that COPD should be acknowledged and championed as a health priority and its prevalence and burden should be included as a national health marker for socio-economic inequality and addressed in a targeted manner.
Scotland	• **The Scotland Programme for Government (2015-2016)** which identifies that Scotland's ambition is to be *'seen as the best place in the UK to do business for its indigenous companies and inward investors, not through a race to the bottom, but by a focus on skills, productivity, innovation and fair work'* and is committed to *'exploiting its world-class research, where businesses turn innovation and ideas into commercial opportunities'*. • **Scotland's Economic Strategy 2015** which seeks to foster a culture of innovation by:

[100] http://ec.europa.eu/health/major_chronic_diseases/policy/index_en.htm

	- Supporting high-impact, world-class research in Scotland's Universities and improving levels of commercialisation of academic research; - Supporting the development of highly innovative businesses across the Scottish economy; - Encouraging Scotland's diverse business base to engage in innovation and R&D. • **NHS Scotland's 2020** vision which aims that by 2020 everyone is able to live longer, healthier lives at home.

In summary, the Evaluation Team is of the view that the BREATH project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

8.11 Barriers to Cross-Border Cooperation

The BREATH project partners have not identified any barriers to cross-border cooperation that the priority axis is not addressing.

8.12 Exit Strategy

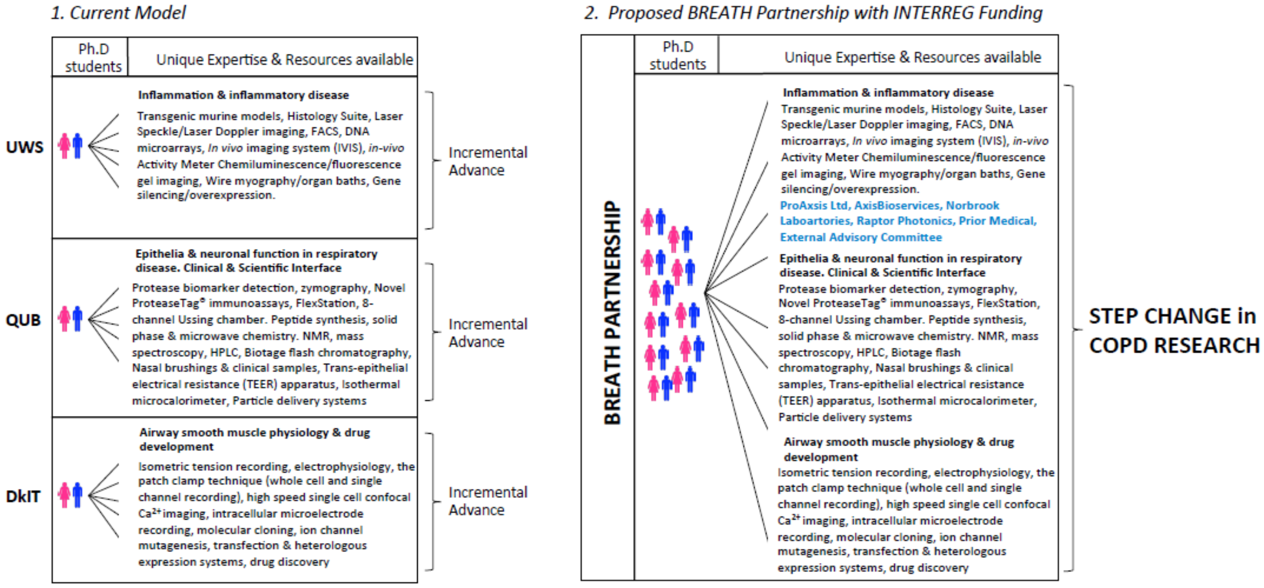
The BREATH project partners anticipate that the long-term impact of BREATH will be ensured by continuing to grow the partnership beyond the current funding period. To do this, they anticipate that they will seek to attract additional funding from both national and international funders as well as industrial collaborations.

Furthermore, the partners note that at the end of the funding period, they expect the research findings from BREATH to be closer to market and, as such, they will continue to work with participating companies to pursue this goal. It is anticipated that commercial exploitation of the research outputs from BREATH will be advanced by PIs, with support from dedicated Technology Transfer Offices in Partner Institutions, to assist in the protection and commercialisation of intellectual assets and the development of industry partnerships.

Whilst the project partners do not anticipate that the project will result in revenue streams within the timeframe of the programme, given its focus on developing novel diagnostics and identifying new targets for the treatment of COPD, they note that they will regularly review opportunities for commercialisation to include a review of innovation disclosures leading to patent. In the long-term (post-BREATH), the partners envisage that there will be potential for revenue streams either through a licensing deal(s) or spin-out company.

The partners further consider that one of the most important elements of their exit strategy will be the creation of a step-change in COPD research in the Region. It is anticipated that this will be achieved by increasing the number of researchers focused on COPD and opening up existing facilities in each Partner Institution across the network. It is envisaged that this pooling of resources will create a critical mass (as depicted below) of researchers that would not be possible without investment from INTERREG.

Figure 8.2: Anticipated Critical Mass of COPD Researchers



9. CPM - CENTRE FOR PERSONALISED MEDICINE

9.1 Introduction

This section of the report considers the Centre for Personalised Medicine; Clinical Decision Making and Patient Safety (CPM) project, which was awarded grant funding under Priority Axis 1a – Enhancing Research and Innovation, Specific Objective 1.1 – Increasing business and industry relevant research and innovation capacity across the region.

9.2 Project Overview

Personalised medicine is a research-based medical approach to guide clinical decisions to ensure a patient receives the right treatment at the right time and is now recognised as a key priority internationally. While the promises of personalised medicine are only now beginning to be realised in certain areas of cancer medicine, in particular, other disease areas have been slow to adopt or benefit from this approach, partly because of a lack of appropriate clinical engagement.

The Centre for Personalised Medicine; Clinical Decision Making and Patient Safety (CPM) project aims to create the oft-cited highly sought-after ethos and environment needed if personalised medicine is to be adapted in the partner hospitals and in five disease areas (research clusters) that have not yet engaged the personalised medicine discipline.

The 5 disease areas are associated with significant morbidity and mortality which are of national/international importance, but which pose particular challenges within the ER, especially the NW of Ireland and Western Scotland (each with their different care systems).

Each RC will carry out research to develop improved clinical care pathways leading to new products and services to address present market failures. The close proximity of two trans-jurisdictional hospital systems with a link to a third provides an ideal opportunity for research and comparative studies.

To this end, CPM's five Research Clusters (RCs) will utilise the methods and technologies from personalised medicine and apply them as follows:

Table 9.1: CPM's Five Research Clusters			
Research Cluster	**Partners:**	**Aim**	**Anticipated Need Addressed**
RC1 Primary coronary intervention (PCI) in myocardial infarction (heart disease)	WHSCT, LUH, NHS H, Ulster, C-TRIC	RC 1: Research and develop an improved cardiovascular risk patient triage pathway. The overall aims of this work plan are: • To improve the clinical decision making within the cardiology department and associated patient journeys, and in particular during the interpretation of the 12-lead electrocardiogram (ECG). • To establish an improved patient triage protocol through the development of novel ECG interpretation software which will result in more effective and rapid diagnosis and treatment of patients. This work has two main objectives: 1) To improve the human interpretation of the ECG; and 2) To improve the machine interpretation of the ECG (or an optimal man-machine model for interpretation).	The rapid and effective assessment of patients presenting with chest pain is critical so that those with myocardial infarction [heart attack] can be referred for immediate coronary artery stenting [primary coronary intervention - PCI)]. Altnagelvin provides a 24/7 PCI service for the west of N. Ireland and Donegal. Raigmore Hospital [NHSH] provides a similar service to the Highlands and Islands. Although a patient triage pathway is in place, WHSCT research shows that although highly sensitive, it has only 30% specificity meaning that large numbers of patients are transferred unnecessarily [often over long distances] for emergency hospital assessment.
RC2 Emergency surgery	LUH, WHSCT, Ulster, C-TRIC	RC 2: Identify determinants of outcome in emergency surgery which will inform the development of improved patient care pathways. This RC will build on the internationally recognised expertise of the LUH emergency surgical team to develop key performance indicators and a comprehensive clinical database. It will identify determinants of outcome in emergency surgery to inform the development of improved patient care pathways, incorporating data analytics, biomarkers, POC and clinician facing software to improve patient outcomes. The proposed outcomes of the project are reducing time to definitive care, optimising diagnosis with point of care testing, streamlining processes to Emergency Surgery, reducing infection, morbidity and mortality, greater understanding of disease process and a transformation of one of the more neglected areas in medicine.	Emergency laparotomy is the most common urgent surgical procedure, with a UK mortality rate of ~15% with wide variation between units. It is a particular challenge outside major centres due to smaller surgical teams and greater reliance on locum/agency staff. Assessment of clinical performance is difficult as it must take into account case mix and patient co-morbidities and is hampered by the lack of validated key performance indicators and data collection and display.

Table 9.1: CPM's Five Research Clusters			
Research Cluster	**Partners:**	**Aim**	**Anticipated Need Addressed**
RC 3 Acute kidney injury (AKI)	WHSCT, LUH, Ulster, C-TRIC	RC 3: Research and develop care pathways to allow earlier AKI recognition and improve the clinical decision-making associated with the management of patients with acute kidney injury. This RC will develop new tools for the detection of AKI through the use of data analytics, biomarkers, POC and the identification of those patients who require prompt treatment and specialist input so that outcomes may be improved. This would involve collaborating with all services involved with the processing of patients in the hospital, including the critical care outreach team, in the stratification of patients at risk of developing acute kidney injury. This work will help in the early identification of those most at risk of developing the most severe variant of acute kidney injury, as well as ensuring optimal management of other patients at risk of AKI. It aims to do so using enhancements of the existing eALERT systems in the Hospital, to both increase awareness of AKI, as well as the steps for its appropriate management.	AKI is a major challenge in acute hospital care – UK research indicates that 16% of acute adult admissions develop AKI which is associated with a longer hospital stay and a 20% three-month mortality. Prompt diagnosis of AKI and early treatment greatly reduces morbidity and mortality. Delays in early recognition mean that ~ 20% of AKI may be considered avoidable.
RC 4 Unscheduled care in diabetes	UHI, Ulster, WHSCT, NHS H, LUH, C-TRIC	RC 4: This RC will research and develop enhanced patient self-management and community clinician management care pathways beyond state of the art. It will improve diabetes management in the eligible region by reducing the need for unscheduled hospital care and admission. These outcomes could include IT such as point of care testing, online algorithms or educational programmes for people with diabetes, their carers or health care professionals or initiatives in health service delivery such as with the ambulance services or telemedicine.	Unscheduled care episodes in diabetes is a problem in the N West; at any time 14-22% of WHSCT hospital inpatients have diabetes as a primary or secondary diagnosis (i.e. above the N. Ireland average of 14.5%).
RC 5 Diagnostic accuracy in dementia.	Ulster, LUH, WHSCT, C-TRIC	RC 5: The overall aim of the dementia research cluster is to make use of large and heterogeneous datasets and advanced computational techniques to improve the diagnosis accuracy of dementia, particularly Alzheimer's disease (AD). This RC will generate algorithms incorporating different data types in an "App" format to increase formal dementia diagnosis rates and permit early intervention and improved access to patient/ family support. This will be realised via the generation of algorithms based on neuropsychological test results, biological and bioimaging markers that allow for improved sensitivity and specificity of AD diagnosis and improved differential diagnosis among dementia subtypes. Development of APPs incorporating some, or all, of the data types, will be undertaken in order to increase formal dementia diagnosis rates in the longer-term. Formal diagnosis allows patients to access treatment and support services that have been shown to improve health and quality of life for both patients and carers and delay institutionalisation (massively reducing overall care costs).	Dementia is a global health care challenge. There is regional variation in prevalence and disparity in diagnosis rates throughout various health trusts. Prevalence is higher in rural Ireland due to the older age profile of the population. Timely and accurate diagnosis is important for the individual, family members and for current and novel emerging treatment choices.

The five cluster areas are considered to be areas associated with significant clinical need and commercial potential and will benefit significantly from the interdisciplinary academic and commercial cross-border expertise and collaboration. On an overall basis, the project partners suggest that the project addresses 'need' on a cross-border basis by:

- Improving the research performance of academic partners across the eligible region;
- Enhancing the innovation performance of companies through academic/industry /clinical partnerships and collaborations;
- Promoting greater sharing of knowledge and expertise among partners in different healthcare systems and cross sectorally;
- Creating a critical mass in the NW and in Western Scotland which can be used internationally to recognise and build on the increasing reputation of CTRIC and the other industry/academic partners;
- Providing a platform for building further alliances to seek other prestigious EU, national and international funding.

It is anticipated that each of the 5 RCs will develop an improved clinical care pathway (incorporating the key overarching themes of a **"Conceptual Framework" - clinical care pathway redesign**, personalised medicine **biomarkers** and **point-of-care (POC) diagnostics)**, for patients through the following steps:

a) baseline data collection;
b) data analysis to identify clinical outcome determinants [including the role of novel biomarkers], clinical care pathway redesign [including the integration of point-of-care diagnostics, decision support software] followed by;
c) prospective clinical evaluation of the redesigned care pathway; and
d) translation to clinical and commercial utility.

Clinical care pathway redesign	Refers to the totality of the process whereby patients are assessed, diagnostic testing is undertaken, a clinical diagnosis made, a clinical management plan formulated and delivered with appropriate monitoring and reassessment. Clinical decision making will occur at each step of the pathway (e.g. what diagnostic tests to perform, what treatment option to choose). Clinical care pathway redesign will be undertaken in each RC to ensure more effective and safer personalised care. There will be collaboration with EP to develop clinician and patient-facing care pathway software incorporating the effective presentation of complex clinical information and to develop decision support software and algorithms.
Biomarkers	A biomarker refers to any measure or indicator of a person's biological state. The biomarkers may include presenting symptoms, proteomic, genomic, metabolomic or microbiomic measurement in body fluids or tissues, etc physiological indicators such as BP, or ECG monitoring. Biomarkers provide information that may contribute directly to clinical decision making through diagnosis, treatment choice, assessment of response to treatment and/or prognosis. Key steps include: • Ethics, governance and recruitment of patients requires prior identification of biomarkers to be used; • Data acquisition and analysis of existing literature and databases to identify suitable biomarkers/biomarker panels; • Assessment of the clinical utility of candidate biomarkers; • Integration of biomarker data with other clinical data; • Integration of biomarker information into clinical care pathways (through POC testing where appropriate); • Integration of biomarker information into smart clinical support decision tools; • Evaluation of the clinical impact of biomarker measurement; • Health economic evaluation of biomarker incorporation in care pathways; • Translation of any commercial opportunities and IP; • Impact healthcare policy.

POC testing	Refers to any diagnostic test performed on body fluids carried out at the patient bedside, clinic, ambulance or at home as distinct from central laboratory testing. The availability of an early test result has the potential to expedite clinical decision making and therefore contribute to improved patient outcomes. As an overarching theme, the potential for POC to be incorporated into redesigned care pathways in the disease-specific RCs will be investigated.

It is anticipated that the CPM project will dramatically enhance regional capability while serving as a magnet for regional and FDI industry to create innovative products and new optimised care pathway tools in priority disease areas for patients and commercial benefit.

The CPM project partners consider that the major strength of the project resides in the expertise of the assembled highly complementary multidisciplinary team of clinicians, academic researchers and enterprises. In total, the project has 12 project partners, with Ulster University as Lead Partner[101]. The other partners are:

2. Western Health and Social Care Trust (WHSCT); 3. Letterkenny University Hospital (LUH), 4. Letterkenny Institute of Technology (LyIT); 5. University of Highlands and Islands (UHI); 6. NHS Highlands Scotland (NHSH); 7. Randox Laboratories Ltd (Randox),	8. United Health Group/ Optum Operations (Ireland) Limited, 9. Clinishare Ltd/Voscuris; 10. Healthcare Analytics Ltd 11. Northern Ireland Clinical Research Services (NICRS) and 12. National Universities of Ireland Galway (NUIG).

The CPM project brings together partners with the array of complementary skills necessary to deliver this complex project [Ulster – expertise in biomarkers, personalised medicine, bioinformatics, intelligent systems, commercialisation; UHI - expertise in rural health research; C-TRIC - POCT, clinical research, commercialisation; WHSCT, LUH, NHSH - clinical expertise, POCT; LyIT – computing , data analytics; commercial enterprises – expertise in biomarkers, POCT, data analytics, software design, commercialisation

Each of the partners is based on the Eligible Region with the exception of NUIG, which has been introduced for their Health Economic and dementia-specific expertise.

The aim is to create a cross border (CB) supercluster of critical mass which will strengthen the CB economy by increasing industry-relevant HLS R&I capability particularly relating to personalised medicine.

The suggested immediate objectives of the project are to:

- Improve the triage of patients with chest pain to allow more appropriate and rapid emergency referral for PCI;
- Identify the determinants of outcomes in emergency surgery to improve care pathways and reduce morbidity and mortality;
- Earlier recognition of AKI to reduce mortality, morbidity and hospital stay;
- Improve the self-management of diabetes to reduce unscheduled care episodes and hospital admissions;
- Develop tools which will allow earlier diagnosis of dementia and therefore earlier clinical intervention and support.

[101] NB This is per the Signed Partnership Agreement (dated 12 October 2017) and not the Letter of Offer (dated 26th June 2017), which features two additional partners (Donegal Clinical Research Academy and Clinical Translational Research and Innovation Centre).

It is envisaged that 5 enterprises will have the opportunity to receive non-financial support including one or more of the following (depending on their success in engaging and innovating in each RC):

a) **Strategic clinical and business intelligence** regarding the suitability and clinical utility of their current products and/or advice on the opportunities for new products;
b) **Access to patient cohorts** to test their products – for example if one or more of the enterprises have existing products such as computational platforms/applications (e.g. patient management software), engineered device(s) (e.g. Point of Care Devices) or biomarkers (e.g. a gene/protein that predicts clinical outcome) that are investigated as part of the project for suitability in contributing to clinical decision making in the Research Clusters, it is anticipated that this will have a very positive value for the enterprise in that ultimately it can contribute to validation of such product(s) in subsequent sales and marketing;
c) **Co-supervision of PhD student(s)** –The project's RC objectives are anticipated to be delivered in large part by the outputs of PhD students (and/or a Research Associate/s) both of which will be frequently co-supervised (and/or advised) by a multidisciplinary team of academics, clinicians and business representatives. Thus, by engaging in this project, it is envisaged that the enterprises will gain extremely valuable expert advice at a very high level that will ultimately have significant value to their business objectives. The enterprise(s) thus derive valuable advice and business intelligence (e.g. the clinical need for a product or the potential suitability of a product in a RC patient care pathway as articulated in the conceptual framework). In addition, each enterprise has a need for a skilled workforce, and it is anticipated that their engagement in this project will enable the enterprise to give input that will inform the generic skills developed and included as a part of the PhD student training programme. Ultimately, it is envisaged that the enterprise will derive benefit from having access to a very skilled pool of talent aligned with their needs;
d) **Co-authorship of peer-reviewed papers:** Peer-reviewed outputs (including REF standard papers) are a component part of the expected output of each RC. If an enterprise is involved in contributing to the outputs that generated the peer-reviewed paper then that enterprise would be either recognised by appropriate co-authorship or cited in the acknowledgements in the paper. Such recognition has a potentially very positive impact on the reputation of an enterprise and gives them a much greater profile (assuming that the result reported is a positive outcome). This may also confer more international credibility to the enterprise(s) involved and will ensure that their product(s) (if used in the study for example) have been evaluated by expert users and external expert peer review at a high level.
e) **The validation of their products in a clinical and research environment** can ultimately be important and valuable for other commercial and regulatory approvals subsequently sought by such enterprises in the translation and impact pathway of product development and as described in the conceptual framework.

The CPM project partners, therefore, anticipate that such non-financial support will be available to all the enterprises engaging with the project, with it suggested that the ultimate value realised in each case will be dictated by:

(i) the level of specific enterprise engagement with the team in one or more RC; and
(ii) by the degree of success and outcomes of in each Research Cluster (which the project partners note cannot be guaranteed in advance of undertaking the project).

The project partners note that it is anticipated that the activities to be undertaken by the enterprise partners will be quite diverse and dictated by the size of the enterprise concerned, the speciality of the enterprise and the existing products or service that a specific enterprise has already available, and how those align with the individual RC objectives.

It is noted, for example, that a larger enterprise such as Randox Laboratories has a mature portfolio of products such as disease-specific biomarker panels and/or engineered devices (e.g. such as point of care devices or laboratory instrumentation). It is envisaged that Randox will donate this specialist equipment and consumables to the project by way of an in-kind contribution (consumables) or loan (equipment) for the life of the project. Randox will also train and manage the use of such equipment across the RCs and provide specialist advice on its use in a clinical setting. Randox will, in return, derive valuable business intelligence from key end-users and potential confirmation of the suitability of their products in their target market sector.

Alternatively, it is envisaged that a small company with a few employees such as NICRS Ltd will advise on and prepare all the ethical applications for submission to Ulster University ethics committee, Office of Research Northern Ireland (ORECNI) and Research Governance permission, and help prepare cross border applications. In addition, NICRS will submit all site-specific information to relevant Trusts and if required for Gateway permission. Other services will include screening and recruitment of eligible participants onto each of the studies; provide a phlebotomy service and/or phlebotomy training for staff and students; blood processing; data collection; and anthropometric and clinical measurement.

Other examples are Clinishare who have developed a patient-centric engagement computer platform, with a powerful mobile-based application capable of presenting every aspect of a patient's medical record and history including test results, imaging and care plans. The backend platform services provide end to end communications and security for all user types whether it be hospital staff, clinicians, laboratory technicians, physicians, payment providers and especially patients.

For the successful management of the partnership and completion of the project, a **Project Board has been** established with Ulster University, as Lead Partner, to ensure the operational delivery of the project. This Board is guided by a **Project Steering Committee** which will meet annually to assess progress against targets in consultation with SEUPB and an **Advisory Board** that will also meet annually and advise on relevant industry, patient as well as governmental initiatives which may impact on the success on the project.

The Project Board is chaired by the Clinical Director of the CPM Project at the WHSCT and has representation from all three jurisdictions and partners, as follows:

- Representatives from Ulster including the Director of Stratified Medicine and a representative from ISRC;
- 1 each from LUH and WHSCT;
- 1 each from UHI and NHSH;
- 1 from LyIT;
- 2 industry reps, 1 each from the disciplines of diagnostics and data analytics, (with a rotational representation)

A senior clinician or academic will lead each of the five transdisciplinary RCs. The RCs will include existing staff from the partners and newly recruited staff. It is anticipated that new staff dedicated to the RCs will comprise 5 Research Director/Research Associates (RA) and 10 PhD students. Whilst each RC has its own dedicated team, they can draw upon the core project staff that will form the **"Cross Border Central Support team"**; and also the expertise that exists within the Partners within the areas of Clinical System Design / Biomarkers / Point-of-Care diagnostics.

All PhD awards will be from Ulster (as the only awarding body electing to engage PhD students), however, the RAs and students will work between all jurisdictions and with academic supervisors assigned to them in each jurisdiction.

Eleven work packages have been developed, as follows:

Table 9.2: Summary of CPM Project Work Plans (per Progress Reports)	
1	Management
2	Biomarkers
3	Overarching Theme: Point-of-Care Testing
4	Overarching Theme: Clinical Care Pathway Redesign
5	Research Cluster 3: Acute Kidney Injury
6	Research Cluster 1: Primary Coronary Intervention (PCI) in Myocardial Infarction
7	Research Cluster 2: Emergency Surgery
8	Research Cluster 4: Unscheduled Care in Diabetes
9	Research Cluster 5: Data Analytics and Modelling for Dementia
10	IP Management/Exploitation and Commercialisation Plan
11	Communication

9.3 Project Budget

The CPM project received a Letter of Offer (dated 26th June 2017) offering a grant of up to a maximum of €8,628,985.36 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €9,424,926.67, as summarised in the tables below:

Table 9.3: Anticipated Project Costs	
Summary Budget	**Total Project Costs (€)**
Staff Costs	4,862,875.74
Office and Administration Costs	1,810,189.85
Travel and Accommodation Costs	128,827.55
External Expertise and Services	1,669,696.44
Equipment Costs	953,337.09
Total	**9,424,926.67**

Table 9.4: Anticipated Project Funding	
Funding Sources	**Total Value (€) (Public)**
Cash Contribution (Partner Supplied/other grant)	512,741.31
In-Kind Contribution	283,200.00
Government Match Funding	1,213,952.79
ERDF	7,415,032.57
Total Grant Funding	**8,628,985.36**
Total Project Costs	**9,424,926.67**
Intervention rate (% ERDF)	79%

9.4 Anticipated Project Objectives, Outputs and Results

9.4.1 Objectives

The project partners anticipate that the collaboration between world-leading RIs, Health Partners (HP); and Enterprise Partners (EP) will result in the achievement of the following objectives:

1. By 1st April 2017, to establish a 'Centre for Personalised Medicine; Clinical Decision Making and Patient Safety (CPM)'.
2. By 1st April 2017, to establish 5 research clusters (RCs):

   - RC1: Primary coronary intervention (PCI) in myocardial infarction
   - RC2: Emergency Surgery
   - RC3: Acute Kidney Injury
   - RC4: Diabetes
   - RC5: Dementia

   each relevant to the priorities of the local population for better healthcare outcomes and with international relevance, and each incorporating the key overarching themes of clinical care pathway redesign, personalised medicine biomarkers and point-of-care (POC) diagnostics, with each RC having an identified Lead and supporting partners;

3. By 1st April 2017, to commence work plans with all selected existing staff allocated to the project.
4. By 1st October 2017, to have all new central and support staff in place recruited – Programme Manager, 6 Research Associates/Director, plus a further 9 specialist staff shared across the RCs.
5. By 1st October 2017, to have 6 PhD students recruited and by 1st April 2018 to have a further 4 PhD students recruited;
6. By September 2017, to have commenced working relationship with Enterprise Partners.
7. To generate research evidence that can contribute directly to improved clinical decision making, resulting in better outcomes for patients locally and internationally who will benefit from new products, processes and/or services and to achieve the disease-specific objectives for each RC by December 2021.
8. By 1st April 2017, to have established a Project Board, chaired by Ulster University who will contribute to, and manage, the project results, outputs, outcome and impact;
9. By 1st April 2017, to have established a Project Steering Committee, comprised of membership from the SEUPB, partner organisations, patient representatives, state agencies and industry, taking account of gender and cross-border regional balances who will provide oversight of the project and to ensure the complementariness of this project with other projects operating in the region;

10. By 1st June 2017, to have established an Advisory Board, comprising key stakeholders, including from Government, Industry and Patient Advocacy representatives who will provide feedback on the project results, outcome and impact and who will benefit from the dissemination of information.
11. By 1st June 2017, to have established a Patient Advocacy Group to ensure patient involvement in study conception, design and organisation, to be drawn from patient support charities.
12. To work in partnership with five Enterprise Partners to translate laboratory and basic science discoveries at levels 3 to 7 on the Technology Readiness Level (TRL), and provide the following to EPs:

    - Access to clinical cohorts from the Healthcare partners;
    - Feedback from clinical or laboratory personnel on the performance of the EP's tests and impact on workflows;
    - Clinical advocacy;
    - Cost-benefit analysis on assays / equipment / protocols;
    - Publications and dissemination of advantages of new protocols;
    - Opportunity to scale into commodity products.

13. To secure by September 2021:
    - 10-12 IP disclosures;
    - 5 UK patent filings, with follow-on International and national filings stemming from those initial UK filings; and
    - One license agreement by Sept 2021.

14. To disseminate research findings, hosting 4 major Academic International Conferences (1 each in 2018, 2019, 2020 and 2021) which will be rotated between Letterkenny and L'Derry; with presentations at additional international conferences, and cumulatively no less than 23 during the period 2017-2021.
15. To assess the economic impact of the findings, with consideration of Economic Evaluation, including Health Technology Assessment and Stated Preferences, Applied Health Econometrics, and Health Policy Evaluations.
16. To achieve 80.5 years' worth of PhD (or above) level research conducted in the eligible area across five transdisciplinary research clusters (RCs) by 30th September 2021. These projected PhD years include:
    - Recruitment of 1 Research Director and 4 Research Associates (all PhD level), and 10 PhD students (two for each Research Cluster) contributing 45 PhD man years;
    - Recruitment of new dedicated staff including Programme Manager, Process Engineer, Biomedical Scientist, Research Associate in Stratified Medicine, and PhD nursing staff member, plus existing Supervisory staff and recruitment of support staff, contributing 32.37 PhD man years; and
    - Enterprise partners having over 40 PhD staff engaged in their industrial research and contributing 3.1 PhD man-years.
    - Additional supervisory input will come from existing staff across Academics, Clinician and Enterprise partners (including at PhD level).

17. To secure 13 peer-reviewed REF-standard journal publications in LandHS journals with cross border authorship and with the potential to create economic impact:

The project partners have also proposed that the CPM project will achieve:

- A minimum of 30 high-quality peer-reviewed publications, abstracts, attendance and presentation of the CPM research findings at conferences[102];
- 5 enterprises cooperating with RIs and receiving support in critical sectors of Clinical and Translational informatics and Data Management Solutions;
- 5 enterprises from across the ER participating in cross-border research projects;
- 5 enterprises from across the ER receiving non-financial support;
- 3 enterprises receiving grants - all SMEs within the eligible area (in part through de minimis and in part through GBER Section 4 registration)[103];
- Employment opportunities for 10 PhDs[104].

[102] The project partners have included a budget for 'gold standard' publishing for the REF standard peer-reviewed outputs. It is anticipated that all of the project's publications will be either Gold or Green access standard and thus openly accessible to all.
[103] The project partners advised that the rationale for 3 enterprises chosen for financial support was based on (a) These 3 enterprises are SMEs (b) are de minimis and compliant with state aid criteria and (c) are the only enterprises in either jurisdiction who requested financial support – other enterprises in either jurisdiction did not request financial support and rather regarded the non-financial support as of very significant strategic importance to their business objectives.
[104] NB the PhD Leaver Survey at Ulster reports that 88% of PhD graduates in 2015 are in employment within 6 months of completion, with a total of 80% employed within the business and academic sectors.

9.4.2 *Outputs*

Per the Letter of Offer (dated 26th June 2017), the anticipated (approved) CPM project outputs are as follows:

Table 9.5: Anticipated Output Targets

Output Indicator	Description	Programme Target	Anticipated CPM contribution	CPM Project % of Programme Target	Commentary
CO01	Number of enterprises receiving support	20	5	25%	In advance of their funding application, the project partners had consulted and engaged with 5 enterprises, that are suggested will receive expert advice and support through the project: • Randox Laboratories Ltd • United Healthcare Group/Optum • Clinishare Ltd • Arc-net Ltd • Northern Ireland Clinical Research Services (NICRS)
CO02	Number of enterprises receiving grants	10	3	30%	It is suggested that Clinishare, Arc-net and NICRS will contribute work packages for which they will receive financial support.
CO04	Number of enterprises receiving non-financial support	20	5	25%	As per CO01, 5 enterprises will receive non-financial support.
CO24	Number of new researchers in supported entities	514	80.19[105]	16%	This will be delivered by 10 PhD students, 2 for each research cluster and 5 Research Associates/Directors.
CO26	Number of enterprises cooperating with research institutions	10	5	50%	It is anticipated that the 5 enterprises listed in CO01 will cooperate with research institutions.
CO41	Number of enterprises participating in cross border, transnational or interregional research projects	10	5	50%	The 5 enterprises included in CO01 will also contribute to the achievement of this output by working on a cross-border or transnational basis.
CO42	Number of research institutions participating in cross border, transnational or interregional research projects	5	4	80%	The 4 academic partners are University of Ulster, Letterkenny Institute of Technology, University of Highlands and Islands and National Universities of Ireland Galway.

[105] Suggested (per Letter of Offer) to be comprised as follows: 10.40 (T1.4.1), 3.70 (T2.1.1), 5.90 (T3.1.1), 9.90 (T4.1.1), 10.00 (T5.1.1), 16.90 (T6.1.1), 10.00 (T7.1.1), 10.30 (T8.1.1) and 3.09 (t9.1.1).

9.4.3 *Results*

The project partners have proposed the following results for the CPM project:

- Produce 13 peer-reviewed REF standard journal publications in the H&LS Sciences field with cross border authorship; and
- 30 other high-quality peer-reviewed publications, (abstracts, attendance and presentation of the CPM research findings at named conferences). During consultation, the Lead Project Partner confirmed that it is assuming that these publications will also need to be cross-border in nature (albeit noting that this is not stipulated within its LoO). It is understood that the Project's Partners are seeking clarification from SEUPB on this matter.

Table 9.6: Result Indicator Target			
Result Indicator	**Programme Target**	**Project Contribution**	**Percentage of Result indictor**
The annual number of peer-reviewed journal and conference publications in two target sectors (H&LS and Renewable Energy) with cross border authorship and with the potential to create economic impact.	75	43	57%

9.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the CPM project's key achievements (as of December 2018) and the extent to which the CPM project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

9.5.1 *Key Achievements (to December 2018)*

The CPM project partners cite the project's key achievements (as of December 2018) as being:

Table 9.7: Key Achievements		
Period	**Dates**	**Key Achievements**
1	1st April 2017 – 30th June 2017	• The 5 research clusters were established;
2	1st July 2017 – 30th September 2017	• Two Research Associates were recruited; • Informal launch of the project at the Translational Medicine (T-MED) conference. Each of the RC leads spoke and had videos of patients developed and presented at the conference.
3	1st October 2017 – 31st December 2017	• Partnership Agreement finalised and signed by all partners; • One PhD was in place as of December 2017 (dementia research cluster); • 3 private enterprises were claiming financial aid (Clinishare, Healthcare Analytics and NICRS); • Health Economics engaged; • Peer review Paper Assessment Panel (PRPA) discussed at the core management team.
4	1st January 2018 – 30th March 2018	Staff • Two PhD students (acute kidney and one further dementia research clusters) started. • Two further PhD students were recruited (cardiovascular research cluster). They were awaiting visas and had expected start dates of May/ June 2018.

Table 9.7: Key Achievements		
Period	**Dates**	**Key Achievements**
		• Staff in LUH recruited for emergency surgery – An administrator and one research nurse started during this period. • UHI research associate started in February for diabetes research cluster and recruitment for a PhD student rather than a postdoctoral researcher was approved by the SEUPB. <u>Research Clusters</u> • Acute kidney disease RC completed its research protocol which was sent to the Office of Research Ethics Northern Ireland (ORECNI) and the Governance Committee. • The cardiovascular research cluster team submitted a paper to the Remote and Rural Health Journal describing pre-hospital care for patients with ST elevations. • Research ethics and Governance approval received for dementia RC and a number of abstracts were submitted to conferences.
5	1st April 2018 – 30th June 2018	<u>Management</u> • Ethical approval received for AKI study and for UHI (diabetes); • Meetings with Randox were held to decide on equipment and biomarker panel selection; • Meetings between NUIG and process engineer to look at potential models for health economics; • Central Technology Group formed; <u>Staff</u> • Research nurses in WHSCT and LUH started (4 in total); • Database manager started in LyIT; • RA/PHD started in UHI (cardio RC); • Director of Research LUH recruited, anticipated to take up the position in August 2018. <u>Students</u> • Three PhD students successfully completed 100 Viva exams; • Networking meeting for PhD students on 13 April to learn about the CPM project with PM; • Two cardiovascular students started during June; • Training undertaking by PhD students on Research Integrity and Good Clinical Practice. <u>Outputs</u> • Generic lifestyle questionnaire drafted for the project; • Paper on Alzheimer's disease submitted to IEEE journal biomedical and Health Informatics; • Two posters on dementia submitted to NI conference - Dementia: Transforming the journey 17 May Templepatrick; • Paper accepted for the journal for cardio RC; • Lab protocols were finalised for the AKI PhD and Research associate for handling blood etc. • Diabetes paper unsuccessfully submitted.
6	1st July 2018 – 30th September 2018	<u>Management and communication</u> • The formal launch of the project was held on 13 September 2018; • Members of the Advisory Board were identified and invited to attend the first meeting on the 16 January 2019. • PURE (repository for UU REF standard scientific outputs) training has been delivered to all UU CPM staff. • The Central Technology Team was set up and will be responsible for ensuring the delivery of the central services in relation to IT, biomarkers, data management and analysis.

Table 9.7: Key Achievements		
Period	**Dates**	**Key Achievements**
		Staff and students • All new staff and students were in place bringing the total number of new staff to 19 and the total number of PhD students 11 (NB the originally proposed UHI postdoc was approved for change to PhD); • 40 existing staff had also engaged in the project. Outputs • Three papers were published or submitted to peer review journals this period; • 10 posters were presented at the TMED conference and one oral presentation on CPM research. Other Achievements • High-performance computing equipment in place in Intelligence Systems Research Centre UU; • Cardiovascular RC had a paper published and two team members invited to speak at an international conference; • Emergency Surgery RC Director of Research started in a post; • Diabetes RC had retrospective data collected for NHS-S and WHSCT; • Dementia RC postdoc in place and amendments for ethics submitted; • Central Technology team were meeting every two weeks. Members included representatives from LyIT, UU, LUH and Voscuris; • Specifications for RCs data storage collected by the central tech team.
7	1st October 2018 – 31st December 2018	• CPM e-zine Issue 2 released during November 2018; • Management Board and Scientific meeting on 31 October 2018; • Management Board meeting in November for IP and Data Sharing • An SOP for the collection and processing of blood and/ or biological samples was created by RA in discussion with the Biomedical Scientist and AKI cluster RA. • Ongoing discussions with Randox for the final decisions on the type of analyser required volume and machine installation timeline. A preliminary analysis was organised for AKI serum samples using the appropriate Randox assays. • Good progress towards defining outcome measures and KPIs by care pathway team, with it, anticipated that a document formally defining these for all clusters would be completed before the end of the next reporting period. • Patient recruitment was underway in the AKI RC and Randox biomarkers selected. • Ethics and governance applications were submitted for cardiovascular (PCI) RC and Emergency Surgery RC and amendments for Dementia RC submitted • Central Technology Team met fortnightly and met with all PhD students and RC leads to gather initial storage requirements; • Emergency Surgery team presented a number of posters at the LUH Research Day in November. CPM team assisted a medical student in preparing for Irish Healthcare Awards which won student project of the year.

9.5.2 Progress towards the Project's Output Indicators

Table 9.8 provides a high-level summary of the progress that has been made by the CPM project towards its Output Indicators.

Table 9.8: Extent of Achievement of Project Output Indicators Targets (as of June 2019)

Output Indicator	Description		Programme Target	Project Target	Progress (as of June 2019)	Variance against target
CO01	Number of enterprises receiving support		20	5	4	80%
CO02	Number of enterprises receiving grants		10	3	3	100%
CO04	Number of enterprises receiving non-financial support		20	5	4	80%
CO24	Number of new researchers in supported entities	T1.4.1		10.40	-	
		T2.1.1		3.70	-	
		T3.1.1		5.90	-	
		T4.1.1		9.90	-	
		T5.1.1		10.00	-	
		T6.1.1		16.90	-	
		T7.1.1		10.00	-	
		T8.1.1		10.30	-	
		T9.1.1		3.09	-	
			514	**80.19**	**32.57**	**41%**
CO26	Number of enterprises cooperating with research institutions		10	5	5[106]	100%
CO41	Number of enterprises participating in cross border, transnational or interregional research projects		10	5	4	80%
CO42	Number of research institutions participating in cross border, transnational or interregional research projects		5	4	4	100%

[106] The CPM project partners note that an enterprise has been providing support to the research clusters as a whole rather than participating in individual research projects. At July 2019, CPM has not yet clarified with SEUPB whether this enterprise is eligible to be included in other Output Indicators such as CO41.

9.5.3 *Progress towards the Project's Result Indicator Targets*

As noted, it was anticipated that the CPM project would:

- Produce 13 peer-reviewed REF standard journal publications in the H&LS Sciences field with cross border authorship; and
- 30 other high-quality peer-reviewed publications, (abstracts, attendance and presentation of the CPM research findings at named conferences). During consultation, the Lead Project Partner confirmed that it is assuming that these publications will also need to be cross-border in nature (albeit noting that this is not stipulated within its LoO). It is understood that the Project's Partners are seeking clarification from SEUPB on this matter.

As at July 2019, 4 peer-reviewed REF standard journal publications in the H&LS Sciences field with cross border authorship have been produced and 17 other high-quality peer-reviewed publications (13 of which have cross-border authorship).

9.5.4 *Progress towards the Project's wider specific objectives*

The CPM Project Partners note the following in relation to the progress made towards to project's stated objectives:

Table 9.10: Project Specific Objectives (at December 2018)		
Project Specific Objectives	**Level of Achievement**	**Explanation**
1. To establish a 'Centre for Personalised Medicine; Clinical Decision Making and Patient Safety (CPM)	To a large degree	The Centre has been established with 12 partners; albeit one partner has yet to submit claims through the eMS.
2. By 1st April 2017, to establish 5 research clusters (RCs)	To a large degree	Each of the 5 research clusters were established and all new staff were in place.
3. By 1st April 2017, to commence work plans with all selected existing staff allocated to the project	To a large degree	all work plans had commenced

9.5.5 *Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives*

Specific issues cited by the Project partners include:

- **Absence of named project lead in LUH continues to delay project progress -** In relation to Research Cluster 4 ('Unscheduled care in Diabetes'), the Lead Partner notes that delays continue due to lack of a named partner in Letterkenny University Hospital to assist the team members to progress the research[107]. As of July 2019, no patient interviews have been completed on this site and the Lead Partner notes that this may mean that the Project Partners will need to plan the main study on this site without the benefit of preliminary data. Ultimately, the Lead Partner suggests that this may impact on the overall success of the main study. Without a named LUH representative on the RC4 team, time is also being lost trying to negotiate access, research approval and recruitment which might delay completion of the 'in-patient' doctoral study.

  Related to the above, a further difficulty that has been encountered whilst implementing the project on a cross-border basis has been navigating the different rules and governance (including gaining necessary ethical approvals) associated with research; and

[107] The Lead Project Partner notes that there is, at the time of writing, a recruitment moratorium at LUH.

- **Concerns relating to the potential impact of 'Brexit'** – Concerns exist amongst the Projects Partners in relation to the potential impact of the UK's withdrawal from the EU on the progress of the project and specifically in relation to data sharing and the transfer of materials. The Lead Partner suggested that depending on the outcome of the ongoing 'Brexit' negotiations a new Partnership Agreement may need to be established; and

- **Lack of communication and cross-project interworking** - Whilst noting that quarterly meetings are held and are led by each of the Research Clusters, one of the Project's Partners suggested that levels of communication between each of the Research Clusters could be improved could be improved and the level of interworking between the research clusters should be enhanced to support greater levels of knowledge transfer.

9.6 Best Practice and Learning

Examples of best practice and learning cited by the project's partners include:

- The delivery of scientific meetings which bring together the academic institutions to facilitate knowledge transfer and good practice; and
- The project is undertaking a retrospective review of patients records to identify opportunities to improve workflow and the management of patients to increase levels of patient care.

9.7 Synergies between Projects funded

CPM's management team at Ulster works closely with the co-located SPIRE 2 and ECME staff across common Doctoral College activities including generic training and development of PhDs and in delivering on the Marie Curie principles for research.

CPM's project partners also note that they have undertaken a number of informal meetings with the other INTERREG VA project managers.

9.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the CPM project's collaborative and partnership working including:

- The effectiveness and added value of the CPM project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

The CPM project partners suggest that they are implementing a number of activities to enhance the effectiveness of cross border collaboration in relation to the specific objectives and new ways of working that would otherwise not be possible in the absence of INTERREG V. These include:

Joint Development	The CPM project partners note that the project's vision is to develop unique solutions to the shared challenges of healthcare delivery in the rural (and cross-border/cross-jurisdictional) setting of the North West of the island of Ireland and the Highlands and Island regions of Scotland. According to CPM, this has facilitated the bringing together of complementary areas of expertise that are necessary for the successful delivery of such a complex project, namely: • Ulster University - personalised medicine research management, commercial exploitation, biomarker development, data analytics, bioinformatics, computational intelligence; • UHI – rural healthcare research expertise; • WHSCT – clinical research expertise, patient cohorts; • LUH – emergency surgery research expertise, patient cohort; • LyIT – data analytics, system design;

	• NHS Highlands – digital health expertise, patient cohorts; • C-TRIC – translational research, industry support; • Enterprise partners – commercial expertise in biomarkers, diagnostic testing, data analytics, software development. The project partners note that clinical studies require large numbers of patients to ensure robust clinical trials and adequate statistical power to ensure reliability and accuracy of the study findings. As a result of the CPM project, the clinical partners [WHSCT, LUH, NHSH] are able to undertake bigger studies than would be possible by any one partner working alone. The collaboration, therefore, provides a unique opportunity for high-quality research on five challenging health care problems facing the predominantly rural populations of the eligible region. The clinical, academic and enterprise partners have jointly recognised the potential of a personalised medicine approach to address these problems.
Joint Implementation	This CPM project is being jointly implemented on a cross border basis in the following ways: • Taking the principles of personalised medicine beyond cancer to other disease areas of cross-border relevance. • Developing and implementing innovative, personalised clinical care pathways for the enhanced diagnosis and management of patients beyond the state-of-the-art in each of the five disease-specific RCs. • In collaboration with enterprise partners, developing novel solutions [clinical care pathway redesign, point of care diagnostics, biomarkers, data analytics, software design] that aim to move beyond current 'state of the art' healthcare delivery. • Building upon the research expertise that exists in Ulster and the North West, (through the NI Centre for Stratified Medicine and ISRC) and the UHI and facilitating sharing of this research expertise/knowledge transfer with clinical and enterprise partners. • Addressing the imbalances that exist in research capability by developing clinical research expertise in Letterkenny and so establishing a strong, sustainable, research cluster in the North West. • Supporting and developing collaboration between the clinical/academic communities and HLS enterprises to foster the development and commercialisation of healthcare products. • Building on the commercialisation expertise, in the field of HLS, that exists in C-TRIC, to be further enhanced with the establishment of Genomic Medicine Ireland at C-TRIC. • Building upon the expertise of Ulster in exploiting IP jointly with commercial partners. Each of the project partners is contributing to the overall implementation of the project and the governance arrangements, with participation in advisory groups, project board/steering committee and patient advocacy groups being carried out on a cross-border basis. Each RC contains cross-border partners to ensure the necessary expertise and critical clinical mass for successful completion and shared learning. It is anticipated that existing clinical and academic staff involved in the RCs will contribute 5% of their time. This will allow clinical staff to oversee patient recruitment and clinical data collection, with oversight and supervision of research staff within their RC. Furthermore, they will provide supervisor/advisory support to PhD students. The project would not be possible without this clinical input. Since clinical staff are contracted only to undertake clinical duties by their hospitals, it would not be possible to release them for the above research activities without INTERREG VA funding to backfill this time.
Addressing Cross-Border Need	The project partners note that the eligible region is characterized by sparsely populated rural areas associated with socioeconomic deprivation, increased healthcare needs, disparities in health and life sciences [HLS] research capability and a small, underdeveloped indigenous HLS business sector. They further note that there are particular and significant challenges in the delivery of high quality health care to rural

	populations: lengthy travel times for patients/carers for both emergency and non-emergency care etc., and that these problems are compounded by difficulties in the recruitment and retention of high-quality clinical staff [manifested by high usage of locum /agency staff]. The project has been developed around five disease areas, each selected because of the healthcare challenges they pose in the ER and the opportunity that exists to align clinical, academic and industrial expertise to develop novel approaches to clinical management based upon the disciplines of personalised medicine. The partners suggest that by combining the complementary clinical, academic and commercialisation expertise of the clinical, academic and enterprise partners, and bringing the disciplines of personalised medicine to these clinical areas, they will be able to enhance rural healthcare delivery beyond 'state of the art' and contribute to economic development in a deprived area through the development of improved personalised patient care pathways, diagnostic tests, data analytics and software-based evaluation tools. Clinical studies require large numbers of patients to ensure robust clinical trials and adequate statistical data to ensure reliability and accuracy of the study findings. By working together, the clinical partners are able to undertake bigger studies than would be possible by any one partner working alone. In addition, the involvement of trans-jurisdictional clinical sites gives depth to the projects and allows the researchers to compare and contrast different but complementary clinical systems.

9.9 Impact on Business and Industry

This section considers the impact of the CPM project on business and industry within the eligible region.

As might be expected given the interim nature of the project's implementation and the continued focus in carrying out the research aspects of the project, the tangible impact of the project on business and industry (in terms of generating outputs and outcomes) can only be measured in the longer term and will be a core focus of the Evaluation Team's next tranche of research.

9.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the CPM project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

9.10.1 EU2020 Objectives

The CPM project continues to offer the potential to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth. Furthermore, the CPM project continues to offer the potential to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

9.10.2 The Atlantic Strategy

The CPM project does not offer the potential to directly contribute to the aims and objectives of the Atlantic Strategy.

9.10.3 The Horizontal Principals

The CPM project partners anticipate that the Programme will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

Sustainable development	The Project Partners consider the environmental impact of the project to be neutral. According to the partners, the project involves no significant travel above what would normally occur. The project team has also sought to use digital communications between site teams, where possible. The project partners acknowledge that any travel between sites will increase the project's carbon footprint but consider that this will be more than offset by the efficiencies gained by improved clinical decision making that will ultimately reduce unnecessary travel or inappropriate hospital stays. The project partners consider that social sustainability is addressed in terms of the rural economic development that the project is anticipated to generate. They note that the cross-border region and Northern Ireland has suffered a negative image due to the conflict that has deterred visitors, inward investors and inhibited local entrepreneurs. The project partners consider that the CPM project will develop capacity at regional levels in terms of encouraging participation, skills development, and regeneration activity through innovative actions from the SME sector.
Equal opportunities and non-discrimination	Ulster University, as Lead Partner, has an Equality Scheme which sets out the University's commitment to and proposals for fulfilling statutory obligations in relation to Section 75 and Schedule 9 of the NI Act (1998). The University promotes equality of opportunity, taking account of all Section 75 groups and in addition, promotes good relations between persons of different religious belief, political opinion or racial group. The University has a system in place for accessing compliance with Section 75 duties, has arrangements for screening and carries out Equality Impact Assessments when required. Also, consultation, monitoring, the publication of assessments and monitoring, as well as training form part of the University's Equality Strategy. An equality scheme action plan accompanies the scheme. These principles have been adhered to in the implementation of this project Ulster University, the University partner in Scotland (UHI) and the hospitals in the different jurisdictions are the main employers of the new and existing posts. Each organisation has rigorous policies that apply, including Equal Opportunities monitoring and reporting procedures. All staff in the universities and hospitals have a stated responsibility to comply with the Equal Opportunities Policy. It is understood that UU has sought to ensure that this has been enacted by having a representative in attendance at appointments panels from other partner organisations. At the outset of the project, all other project partners were informed of their requirement to adhere to statutory Equal Opportunities Policies. The CPM project partners indicate that this has been monitored by the CPM Programme Manager.
Equality between men and women	In order to address the under-representation of women in science, Ulster has received a bronze award in the Athena Swan Charter in 2014. This Charter recognises and celebrates good employment practice for women working in science, technology, engineering and maths (STEM) in higher education and research. The Bronze Award submission included a three-year Action Plan aimed at supporting and developing the careers of women in STEM at Ulster. Ulster University, as lead partner, has sought to ensure that all partners working in the project will ensure equality of opportunity during the management and implementation of the project and that the principles of the Athena Swan Charter are promoted across the partnership. For the CPM project, the partners note that the Research Clusters includes 1 female lead and 5 female contributing clinicians and academics, plus female Research Nursing staff.

9.10.4 Contribution to Other Strategies

The Project Partners consider that the CPM project has the potential to contribute to a number of economic and healthcare-related strategies in each of the three jurisdictions, including:

- **NI strategies** including the draft Programme for Government 2016 – 2021, NI Innovation Strategy, Life and Health Sciences strategy, the Health Innovation and Life Science Hub, the DHSSPS Research for Better Health and Social Care (2016-2025) strategy, Innovate UK and Invest NI;
- **Republic of Ireland strategies** including SFI and Agenda 2010, Enterprise Ireland, IDA Ireland and the Health Research Board; and
- **Scottish strategies** such as SG 2020 vision for healthcare, Commission on the future of public services and SG eHealth strategy.

Furthermore, at a disease-specific level, the project partners note the following:

RC1:	Aligns with the British Heart Foundation, the national agenda for healthcare research in the ageing population, and the European commissioned societal challenge on 'Health, Demographic Change and Wellbeing'. Research into patients' safety [medical error detection/prevention] is a national priority as evidenced by the fact that the NHS established a National Patient Safety initiative.
RC2:	Aligned to National Policy in the Acute Surgical programme, which was led out by the Royal College of Surgeons in Ireland in conjunction with the Acute Hospital division. Their publication this year will be an endorsement of the project and already many of the leaders of that project have been involved in the DCRA's Emergency Surgery programme. In addition, this project will align with the Nuffield report, recognising nationally, both in the UK and in Ireland, the need for safety and tailoring individual care to individual patients.
RC3:	Reducing risks of AKI, as well as improving the care of patients with AKI is an important part of renal care strategy that has been supported by the NHS, UK Renal Registry as well as the UK NICE and is also consistent with the stated aim of the Irish National Renal Office with objectives of developing patient-centred Renal Services, and to improve the outcomes of renal patients, using integration of health facilities.
RC4:	Aligns with the NI Transforming Your Care Review, Diabetes Ireland's future vision for diabetes management, the 2020 Vision for Health Care in Scotland (2012) and the National Clinical Strategy for Scotland (2015) – all promoting patient safety, clinical effectiveness and person-centred approach with the need for new models of care delivery.
RC5	Addresses R&I priorities identified in recent governmental initiatives aimed at urgently better understanding and managing dementia within UK and Ireland - highlighted by National Alzheimer's Society and Alzheimer's Research UK reports, Alzheimer's Research UK NI Network Centre, Dementia and Neurodegeneration Ireland (DNDI), and work already at Ulster.

The project partners further consider that the project:

- Aligns with the UK NHS National Genetics Education and Development priorities, the UK Government NHS priorities outlined in The Human Genomics Strategy Group (HGSG) report, Building on our inheritance: Genomic technology in healthcare - A report by the Human Genomics Strategy Group. January 2012; and in the 2015 Academy of Medical Sciences Report, and Genomic Medicine Ireland; and
- Fits with overarching policies relating to personalised medicine as well as disease-specific policy drivers, in particular by bringing the principles of personalised medicine beyond cancer to other disease areas of cross-border relevance where there has previously been a lack of appropriate clinical engagement.
- Aligns with the objectives of the UK Personalised Medicine Catapult Centre and its regional hub in NI.

9.11 Barriers to Cross-Border Cooperation

This section considers whether the CPM project has encountered any barriers to cross-border cooperation that the priority axis is not addressing.

The Project Partners suggest that a key issue encountered is the lack of control that the Lead Partner has over project implementation within partner organisations and the dependency therein on individuals in other organisations to drive the project forward. It was noted that this is particularly the case when a partner organisation might not have similarly extensive experience in research management as other organisations in the project partnership.

Related to this point, CPM suggested that SEUPB should provide training to project partners relating to the eligibility of different expenditure items and methods to manage budgets across partners.

9.12 Exit Strategy

This is a significant project with the opportunity to bring personalised medicine into five new disease areas and thus has significant potential commercial applications. Indeed, the project partners envisage that, at least, one licence will be secured within the project timescale, and anticipate that income from this will, therefore, flow post project completion. They note that any other translation of IP generated will be aimed at forming the basis of new commercial revenues with income shared based on the IP agreements between the partner organisations.

The majority of anticipated outputs generated from this project are anticipated to be created through a unique cross border academic, clinical and industry partnership. The project has been structured to ensure that academic learning from the project can be readily implemented in a clinical setting to both enhance patient safety and also to ensure greater efficiency in the delivery of Healthcare.

It is anticipated that the employment of a Health Economist, as part of the project team, will enable the project team to clearly identify and cost the savings to be made through enhanced interventions.

Additionally, the project partners suggest that the collation of baseline clinical data and the ongoing collection and analysis of data throughout the project will enable the project partners to clearly illustrate the benefit of the enhanced interventions developed in the course of the project, and therefore encourage relevant agencies to continue with the work undertaken in the initial project.

According to the project partners, as a result of the expertise and worthwhile academic, clinical and industry collaborations developed in the course of the project, they envisage that industry commercialisation will arise and that additional projects will emerge which will attract funding from a range of sources including government sources and research councils. Furthermore, they believe that the incorporation of transnational industrial partners will enhance the opportunities for attracting research monies from further afield.

Whilst, at the time of writing (June 2019), it is too early to determine where the project's PhD students' careers will take them, the CPM project partners suggest that it is likely that the learning and expertise that they will have gained through the project will be fed back into industry and academia. Ulster University's research has shown that research students generally achieve a very high degree of employment following graduation. In the three most recent Destination of Leavers' surveys, 89%, 85% and 88% of research degree graduates had achieved employment within 6 months of completion.

10. CO-INNOVATE – THE INNOVATION PATHWAY PROGRAMME

10.1 Introduction

This section of the report considers the Co-Innovate programme, which was awarded grant funding under Priority Axis 1b – Promoting Business Investment in Research and Innovation, Specific Objective 1.2 – Increasing the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services.

10.2 Project Overview

It is recognised that there is currently too few innovation-active SMEs in the eligible region. This is recognised in the economic and innovation strategies for the different parts of the region[108], which identify common barriers, such as:

- A high proportion of enterprises are small;
- The costs associated with innovation are perceived to be prohibitive;
- Resources and/or absorptive capacity within firms are inadequate for successful implementation;
- Firms have limited access to finance; and
- Firms have limited access to business and academic/research partners.

Despite the efforts of the agencies, these challenges persist. In each of the three jurisdictions – Scotland, Northern Ireland and Ireland – targets have been set to move up the EU and UK innovation rankings by increasing both business expenditure on R&D and the numbers of firms innovating.

Objective 1.2 of the Cooperation Programme sets out the need to increase the number of innovation-active SMEs in the eligible region, to assess and improve their capacity, and to address the barriers to innovation, by increasing cross-border collaboration with other innovation actors.

InterTradeIreland's (one of the Co-Innovate project partners) own research suggests that the key constraints on SME innovation are capability deficiencies in firms and the challenge of managing connectivity to the broader R&I ecosystem. Their research[109] indicates that SMEs across the region, particularly smaller ones, tend to draw on their own resources when innovating, and when they adopt a more open approach, they tend to do so in a narrow fashion, engaging mainly with customers and suppliers, rather than with research institutions or other factors.

In order to help alleviate such issues, the Co-Innovate Programme aims to facilitate and support cross-border connectivity between enterprises and research institutes. The Programme brings together, for the first time. key development agencies within Ireland, Northern Ireland and Scotland to deliver a comprehensive cross-border SME innovation capability development programme. The lead partner, InterTradeIreland, has a unique track record in designing, developing, delivering, monitoring and evaluating effective and efficient cross-border R&I programmes for SMEs. The other partners are:

- Scottish Enterprise and Highlands and Islands Enterprise, Scotland's economic development agencies;
- Enterprise Northern Ireland (Enterprise NI), the representative Body for the local enterprise agency (LEA) network in Northern Ireland;
- The Local Enterprise Offices (LEOs) in the border counties of Ireland; and
- East Border Region Ltd (EBR), who brings experience in the financial management of EU-funded programmes.

[108] DJEI, Enterprise 2025; DETI, Northern Ireland Innovation Strategy, 2014-2025; Scottish Enterprise, Innovation Strategy, 2015-2018
[109] InterTradeIreland, Leveraging the Innovation Ecosystem for Business Advantage: A Cross-Border Study, December 2012

The programme aims to increase the proportion of SMEs engaged in cross-border research and innovation (R&I) collaboration within the eligible region, from 22% (2014) to 33% (2023). It intends to engage with over 1,408 SMEs, providing them with education, capability development and support according to need and absorptive capacity.

Using its knowledge and experience of developing innovation capabilities and collaborative opportunities for SMEs, the Co-Innovate project partnership has developed an integrated programme that includes:

- Workshops delivered by innovation experts familiar with the challenges facing SMEs;
- R&I capability assessments tailored for SMEs;
- Enterprise-specific action plans designed to develop R&I capabilities;
- Intensive mentoring to address specific challenges;
- Active engagement in cross-border R&I partnerships; and
- Sector-specific networks involving enterprises and research institutes.

The project partners consider that the Co-Innovate Programme will be unique in that it will provide an integrated pathway to address capability deficiencies through audit-based mentoring and advice before facilitating new cross-border connections.

It is anticipated that the programme will help SMEs identify and understand the barriers that constrain their innovation activity and thus limit their growth potential. The programme will work with the firms to identify their capability deficiencies and point them to the most appropriate supports – which may be other elements in the Co-Innovate Programme or other supports available in their region to improve their innovation capability. The project partners consider that the programme, therefore, represents a holistic and comprehensive approach, coordinating with and mobilising existing R&I supports across the entire eligible region, to progress SMEs with identified growth potential from being relatively innovation-inactive to full participation in collaborative cross-border R&I partnerships and networks. In relation to this aspect, both Enterprise Ireland and Invest NI have agreed to establish an Advisory Board in order to ensure that enterprises are directed to the most relevant supports available and to avoid duplication. In Scotland, Highland and Islands Enterprise and Scottish Enterprise are the Scottish Government's agencies with responsibility for delivering business support, including all R&I supports, to SMEs. These agencies are also represented on the Advisory Board in order to ensure a coordinated approach that aligns the Co-Innovate Programme with existing supports.

It is anticipated that SMEs participating in the Co-Innovate Programme will[110]:

- Promote and stimulate a culture of R&I;
- Inject and embed sustainable innovation management practices;
- Create positive changes in market growth, jobs, wealth creation, investment in product development, and new products, processes and services;
- Invest more in human capital, leading to improved skills, productivity, performance, recruitment, staff retention and reduced absenteeism;
- Share knowledge and experience in R&I with other SMEs and with educational and research institutions;
- Promote open Innovation and improve access to the innovation ecosystem across the eligible area;
- Avail of cross-border and inter-regional collaboration opportunities;
- Improve their capacity for sustainable development.

Ultimately, the project partners suggest that enterprises completing the programme will develop new products, processes and services and improve their growth trajectory.

[110] NB the project partners have advised that they will tracking and recording each of these desired benefits through the implementation of a comprehensive Benefits Realisation Plan. In addition, Where appropriate participants will be asked to identify and quantify any increase/decrease in turnover, export sales, employment levels, business confidence, and level of R&I activities.

In terms of data capture, the project promoters have advised the following:

Upon commencement of each of the Co-Innovate Programme strands, each participant will provide the following baseline information:	• Total value of annual sales/turnover (for the last financial year) • Total annual sales in the cross-border market • Total number of employees (measured in full-time equivalents).
On completion of the programme, each participant will provide the following information:	Details of any: • Increase in sales/turnover attributed to participation in the Co-Innovate Programme; • New markets entered as a direct result of the programme or indirectly through being referred to during the programme; • Referrals to other forms of support and any benefits accrued; • Supply chain impacts e.g. reduced costs, new suppliers, etc.; • New processes or products developed as a direct result of the programme; • Referrals to other agencies and/or relevant programmes; and • Collaboration activities entered into as a result of participating in the programme.

It is anticipated that the Co-Innovate Programme will focus on SMEs from manufacturing and tradable services, with specific priority afforded to enterprises from the Renewables, Life and Health Sciences and Agri-food sectors.

The project will be delivered in five strands, as illustrated in Figure 10.1 and Table 10.1.

Figure 10.1: Co-Innovate Programme Strands

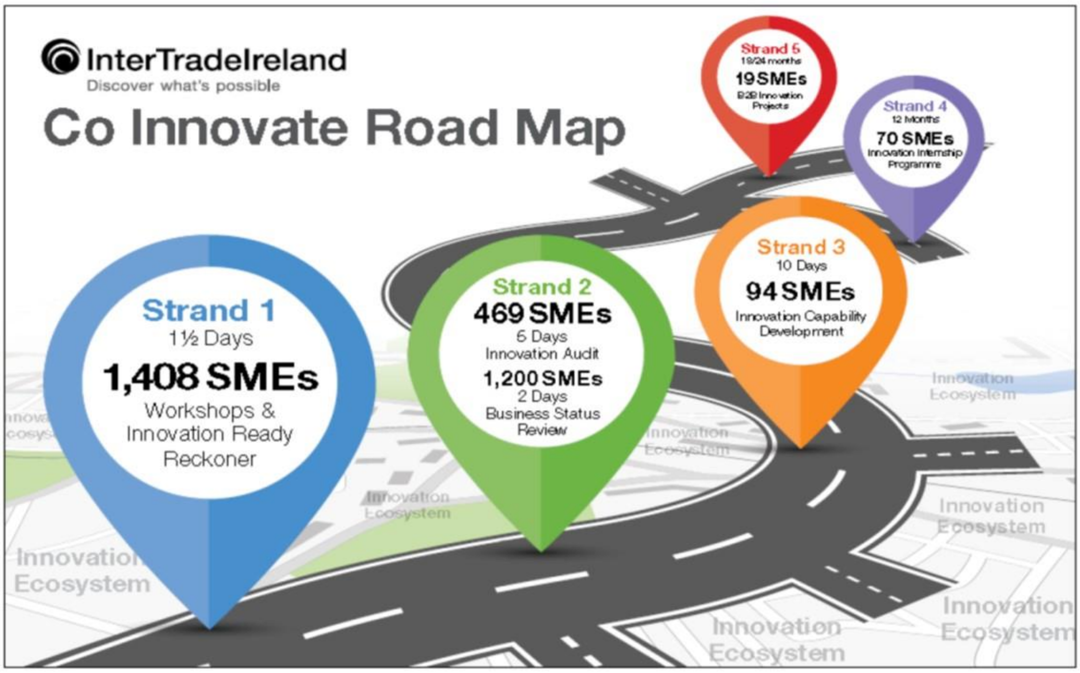


Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
1. Innovation Ready Reckoner and Workshops	'Strand one' is the primary recruitment opportunity for SMEs to the programme. It acts as the initial 'gateway' for most SMEs to participate on the initial and subsequent strands and hence is considered to be the most important stage in the process. In Strand 1, it is anticipated that 1,408 SMEs will be recruited onto the programme. Concurrent with the recruitment of businesses, it is envisaged that 108 R&I workshops (86 non-sector specific workshops and 22 sector-focused workshops[111] at locations across the eligible region) will be delivered across the eligible region ensuring equality of access for SMEs, with each attended by up to 30 SMEs. The project partners have proposed that participant SMEs will be drawn from the manufacturing and tradeable services sectors. SMEs will be identified as suitable to participate on the programme following intensive pre-workshop engagement between the local partner and the SME. Given that eligible SMEs must demonstrate some level of innovation capability, this initial engagement will include a preliminary innovation diagnostic/assessment (use of the Innovation Ready Reckoner – IRR[112]), capture of sufficient baseline data and completion of an online application form, which will enable shortlisting of the most suitable SMEs. It is envisaged that the completion of the IRR will ensure that as many SMEs as possible will benefit from some form of innovation 'takeaway' regardless of how far they progress on the programme. The IRR aims to capture high-level data including the extent to which the SME already innovates, the quantum of innovation, use of knowledge and technology, idea management and implementation, leadership and culture. Delivery of this aspect is anticipated to be by experienced personnel provided by Local Enterprise Agencies in Northern Ireland, in Local Enterprise Offices in Ireland, and in Scottish Enterprise and Highlands and Islands Enterprise in Scotland. It is envisaged that the 1,408 shortlisted SMEs will be invited to attend either a generic innovation workshop aimed at SMEs from many sectors or a sectoral workshop aimed at SMEs operating in the key sectors identified - renewables, life and health sciences and potentially agri-tech/food. However, according to the project partners, many more than 1,408 SMEs will be engaged with pre workshops and both natural attrition and shortlisting will ensure than only the most suitable SMEs progress to a workshop. It has been proposed that each workshop will run for a half-day with attendees receiving useful collateral to take away and study. The workshops will aim to educate SMEs on the benefits of innovation, improve their understanding of the innovation ecosystem on a cross border basis and improve their capability to benefit from it. Cross border participation in workshop attendance will be actively promoted to encourage peer to peer networking among like-minded SMEs and sharing lessons learned from innovation case studies. The project partners recognise that the main risk associated with the project is the recruitment of sufficient quality of SMEs to progress to later strands i.e. SMEs who have the financial capacity and desire to invest in later strands. However, the project partners have proposed that their experience and robust recruitment plan will mitigate this risk, alongside the implementation of a rigorous	Greater awareness of the need for R&I in business and of ways to develop R&I capability

[111] Including in the key target areas of renewables and life and health sciences to ensure that a sufficient number of SMEs from these target sectors attend the workshops and progress to later strands.
[112] The project partners suggest that the Innovation Ready Reckoner is a more 'light touch' tool, compared with the comprehensive innovation audit that features within Strand 2.

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	IRR assessment (and Business Status Review process and Innovation Audit), which will serve to help ensure that only "quality" SMEs capable of progressing through the various Strands are approved on to the programme.	
2. Business Status Review and Innovation Audit	'Strand two' of the programme is a series of one-to-one innovation interventions offered to SMEs who have been shortlisted or expressed an interest in progressing after their participation in strand one. SMEs that have participated on strand one will now be aware of the benefits of embracing and utilising innovation to help grow their business and they will have a wider understanding of the local and cross-border innovation ecosystem. This strand is an opportunity to work with the SME on a one-to-one intensive basis to explore further areas for growth with innovation. SMEs who progress successfully from the workshop to Strand 2 will avail of a Business Status Review which will explore among other things existing and potential export opportunities. The Innovation Audit undertaken will identify the innovation needs and steps required to develop new products and processes for the development of new and existing export markets. The first objective of the strand is to identify those SMEs from strand one workshop attendees with potential to progress to a more intensive innovation activity, the innovation audit. It is anticipated that 1,200 SMEs (85% of 1,408) attending strand one workshops will express an interest in progressing to strand two and each of these SMEs will receive a Business Status Review (BSR - 2 days per company) undertaken by an advisor (in NI/Ireland drawn from a procurement framework and in Scotland carried out by an innovation manager) with a recommendation on suitability to progress to innovation audit stage. Following a pre-identified template, the BSR will assess in detail the SME's underlying business issues which may/may not hinder their ability to fully embrace innovation. It is anticipated that the BSR (with recommendations) will take two days per SME to complete. The proposed breakdown of BSRs across the eligible region is NI 595 (50%), Ireland 306 (25%), Scotland 299 (25%). After carrying out the BSR, the expert will make a recommendation on suitability to progress (or not) and following approval by the assessment panel 520 SMEs will progress to the innovation audit stage. It is anticipated that, following natural attrition, 469 will conclude the innovation audit (5 days per company) including the associated action plan with recommendations for suitability to progress to later programme strands. The breakdown of innovation audits across the eligible region is NI 232 (50%), Ireland 119 (25%), Scotland 118 (25%). The in-company innovation audit will consider the findings of the Innovation Ready Reckoner completed in strand one and the BSR and subsequently identify capability deficiencies, strengths, needs and opportunities for research and innovation. The documented outcome will include preparation of a bespoke innovation action plan which will address capability deficiencies and opportunities for innovation that can be conducted on a cross-border basis and recommendations signposting the SME to strand 3, 4 or 5 of the programme or to alternative supports across the eligible area. It is anticipated that the Innovation Audit will take 3 days to complete to allow time for an intensive one to one meeting between the expert undertaking the innovation audit and the SME, write up of report with recommendations and travel. It is envisaged that a key element of undertaking the innovation audit will be the full engagement of the CEO or senior management team. This level of engagement is considered crucial at this stage and stems from the lead partner's experience of similar interventions. Further time allocation has been factored in for a transition to the next stage/audit interpretation meeting. This meeting will involve the expert who carried out the innovation audit, the SME and in the case of the NI and Ireland regions the local enterprise agency/office contact. The purpose of this interaction is to ensure the SME (and local contact if appropriate) understands the results of the audit, provides an opportunity for personalised signposting to other innovation supports and how these can be built on to	Participant SMEs have a thorough understanding of their R&I position, and a clear action plan to achieve their aims and objectives

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	ensure there are legacy benefits in place once the SME's participation in the formal programme comes to an end. This stage is particularly important for SMEs who do not progress to later strands of the programme. This stage will also ensure that SMEs drawn from the target sectors of life and health sciences and renewable will be made aware of the opportunities that exist from working with research institutions and network projects involved in Investment Priority 1a Enhancing Research and Innovation.	
3. Innovation Capability Development Programme	Strand 3 of the Co-Innovate programme is an intensive in-house innovation capability building programme. The purpose of this work package is to assist SMEs to improve their innovation capabilities in order to more effectively engage in collaborative cross-border research and innovation partnerships. Tailored support will be provided to SMEs in the form of technical and innovation expertise (academic or consultant), drawn from a procured framework, who will work intensively with the participating SME. The value of the support is capped initially at €7,000 per SME and will deliver approximately 10 days support over a 5-month period. Based on the project partners' experience of delivering similar programmes, an attrition rate of 15% is anticipated. Therefore, a total of 110 SMEs will be approved by the assessment panel to progress onto Strand 3 with the expectation that 94 will complete. In the previous strand, 469 SMEs will receive an innovation audit. From this, a report will be produced providing a holistic view of the status of innovation in each SME, including an action plan for future activities. The report, signed off by the SME, will contain recommendations on how best the SME should be signposted to progress through the Co-Innovate Programme. This may be a recommendation to progress to strand 3, to strand 4 or 5 or an alternative option. It is expected that where reports identify specific capability deficiencies that are impeding the potential to collaborate and innovate, participation in Strand 3 will be recommended. In this instance, the report will be reviewed by the Co-Innovate assessment panel, at their bi-monthly meetings, who will consider the recommendation and either approve or reject the progression. The innovation audit report will identify a diverse range of capability issues given the sectoral, managerial and geographic differences in the participating SMEs. Operating a framework across the entire eligible area, which is open to consultants and academic experts, will provide the participating SMEs with access to the very best available technical and innovation expertise that will impact their innovation capability and their prospects of engaging in a cross-border collaborative R&I project. When SMEs are approved by the assessment panel onto Strand 3, they will be matched with the most suitable expert from the procured framework. The lead partner will be responsible for the initial shortlisting of suitable experts from the framework, from which a mini-competition will identify the optimum expert. All SMEs will be assigned to a local member of the programme delivery team. These will be involved in the mini-competition to identify the best expert for the SME. They will be responsible for coordinating and overseeing the engagement between the SME and the expert and ensuring delivery of outputs against targets and timeframe. They will also act as an honest broker to handle queries and address delivery challenges. At the conclusion of Strand 3, the programme delivery team will assist SMEs with the progression to either strand 4, strand 5 or alternative supports across the eligible area.	Enhanced innovation absorptive capacity for SMEs.
4. Cross-Border Innovation Internship Programme	Strand 4 matches SMEs with an academic or researcher (provided by an academic institution or research institute registered on a procured framework). These partners then work together to develop a 12-month work plan resulting in new product, process or service development. The SME is assisted (by the Co-Innovate Programme) to recruit a suitably qualified intern and to employ the intern as a 'Project Manager' for a 12-month period.	Jobs created, investment in human capital and the development of new products and processes

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	While these projects are anticipated to be challenging both for the SME and the intern, the Programme partners believe that, with the level of support proposed in Strand 4, 12 months is a sufficient period for the project partnership to deliver real benefits for all the partners and to put in place the links for continued cross-border collaboration following the conclusion of the project period. Recommendations (an output of the Innovation Audit Action Plan) from all the regions for SMEs that have the need and potential to take part in Strand 4 will be assessed and approved by the Strand Manager and then circulated to the Technology Transfer Offices (TTOs) of Academic Institutions on the framework. It is anticipated that 70 SMEs (27 in Northern Ireland; 26 in Ireland; 17 in Scotland) will subsequently engage a graduate to undertake a 12-month cross-border research project in partnership with an academic/research institution. It is noted that the project partners have proposed that to ensure 70 completions, 115 applications will be presented to the Assessment Panel, 105 projects will be approved, with 80 projects planned to start. The Academic Lead(s) are expected to advise on the skill set required and assist the company to appoint the correct individual including being involved in the recruitment process and being part of the interview panel. Key benefits for participating businesses are anticipated to include: • Up to 28 days Academic Institute support for each SME (including 3 consultancy days provided by Academic Institute to develop the project proposal application on behalf of the business); • Up to 50% of Project Manager Salary for 12 months of €20,000 (i.e. a maximum salary of €40,000); • Support for travel & subsistence to deliver the project. • Gain support from and access to the specialist knowledge and resources within leading Academic Institutes. • Develop the company's knowledge and capabilities while embedding innovation for the future. • Accelerate the development of their product/service/ process to drive their businesses' competitive advantage and boost their bottom line. • Benefit from the additional dedicated support the Project Manager will bring to the company while receiving expert advice from the experienced Academic Leads. • Project management support from the Co-Innovate team. Academics/researchers interested in working on each individual project will submit their Expression of Interest, through their TTO, to the Strand Manager who will manage a fair and transparent process of matching (through a Strand Selection Panel) the most appropriate individual (s) to each SME. An initial scoping meeting will be held involving the SME, academic and Programme Delivery Team staff to ensure agreement on the way forward for the project partnership. This meeting is considered vital to build confidence in the partnership and ensure buy-in from the SME and the academic as to the practical and technical feasibility of the project. The academic will then take the lead in preparing an application form for assessment by the full Programme Assessment Panel. This form will include the rationale for the project, expected outputs and benefits for each party, a full personnel specification and detailed work plan. As part of the assessment process, Programme Delivery Team staff will review the most recent financial accounts	

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	information for the SME and will liaise with other Business Development Agencies to ensure there is no double funding or any other issues of concern. Programme Delivery Team staff will manage the process of feedback to successful and unsuccessful applicants and will manage the re-application process if required. For successful applicants, Programme Delivery Team staff will manage the process of attracting graduates, posting jobs on appropriate websites and ensuring the shortlisting and interview process is carried out according to best practice and in accordance with recruitment legislation. Following the appointment of an intern, Programme Delivery Team staff will attend a meeting between the SME, academic and intern to initiate the project and then will monitor progress through phone call support and formal quarterly face to face meetings. The meetings will follow a standard agreed agenda. The intern will manage the project and the academic will on average dedicate two days per month to the project. Programme Delivery Team staff will also support SMEs and academics through the financial claims process and ensure that a comprehensive final report capturing the benefits and learnings is submitted. The project partners note that during the project and following completion, as there is a programme focus on the key sectors of Renewables and Life and Health Sciences, it will be key to ensure all relevant SMEs are advised of the opportunities available within Investment priority 1A. The Programme Delivery Team will work closely with all relevant partners to promote collaborative R&I opportunities.	
5. R&I Partnerships	The objective of Strand 5 is to develop and deliver 19 Research and Innovation partnerships; comprising: • 15 company to company collaborations - one SME from an eligible region working with another SME from the other eligible region on a specific R&I project on a cross-border basis[113]; and • 4 innovation network/cluster projects – which will include at least one research institution and SME working together on a cross-border basis on an innovation network in the four identified sectors. The sectors are Renewables, Life and Health Sciences, Agri-food and one market opportunity driven network. It is anticipated that each of the 4 network projects will include representation from each part of the eligible region, i.e. Scotland, Ireland, Northern Ireland in the form of SME or research institute. Each project will be of a 2-year duration and receive grant assistance for their co-operative R&I activity to develop a new product/process/service/system. There is a focus in this stage in establishing network projects in the Life & Health Sciences, Renewable Energy, and Agri-Food sectors, but the programme is not limited to these areas only. The Programme offers: • Up to €7,000 funding for resources to complete a feasibility study and a full business plan application for the R&I project.	Increased performance, capability and profit for SMEs; innovation networks

[113] The project partners note that they anticipate that at least 30 SMEs will receive a specific offer of grant aid based on the particular needs of their successful collaborative application.

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	• Grant per business to a business partnership of up to a maximum 50% eligible funding capped at €150,000. Co-Innovate is looking for ambitious businesses across the island to collaborate and form a strategic innovation partnership with another company to get great products and services off the ground • Grant per innovation network cluster up to a maximum 50% eligible funding capped at €300,000. Each cluster which is supported by the Co-Innovate programme will involve a group of companies and at least one academic partner (a minimum of three business organisations and one academic institute). Funding provided will be for a very specific purpose and the results of the cluster activity will have some identifiable and measurable impacts for each partner. Specifically, a business network is likely to result in an enhanced competitive advantage and/or mutual financial gain. The type of SME to be engaged will be one that has significant export scale potential and has the absorptive capacity to undertake a collaborative R&I project. The 15 business to business partnerships will receive grant assistance for cooperative R&I activity. This Strand will focus on priority areas of Life and Health Sciences, Renewable Energy, and Agri-Food. Other anticipated outputs include 5 Research Agencies involved in cross-border/transnational/interregional partnership projects: 2 in Northern Ireland; 1 in Ireland; 2 in Scotland. The Programme Delivery Team (hereafter referred to as PDT) will focus on those SMEs successfully completing Innovation Audits (Stage 2) who are recommended as best able to undertake collaborative research and innovation activity. A rigorous collaborative development process will be undertaken. The Programme Development Team will be instrumental in raising awareness, particularly among the highlighted sectors of Renewables, Life and Health Sciences and Agri-Food. The specific process will include Expressions of Interest, peer assessment, partially funded business plan development, independent technical and commercial assessment and facilitated project management support through the implementation stage. The Programme Delivery team will use the output of Strand 2 Innovation Audits to engage with interested and identified SMEs to assist the partnership development process including site visits. They will also use their knowledge of the local SME base to identify suitable partners and this will include attending and actively participating in strand 1-3 activity and all related communications activity. This activity may include Technology Transfer Offices at Universities, Colleges and other academic centres. The team will prepare PR material to launch a series of “competitive calls” to promote the Stand 5 opportunity. A series of focussed competitive Calls for "Expressions of Interest" (EoI) will be widely advertised across the eligible region; with a minimum of three focusing on Business to Business collaborations and one dedicated Innovation Networks projects call. This will ensure the opportunities are widely available to all SMEs within the eligible region. The Programme Delivery Team will engage with interested and identified SMEs to develop the partnership process including site visits. They will assess the EoIs against pre-determined criteria and present recommended applications to the Assessment Panel. Successful projects, at this stage, will be issued with a Letter of support, which includes completing a short funding request for resources to complete the full business plan application. It is the partnership’s view that providing funding will mitigate the risk of a poorly completed business plan, whilst a financial investment from a collaborative partnership demonstrates their commitment to the process. The Programme Delivery Team will prepare the full business plans for presentation to the Assessment Panel. Each submitted plan will be subject to an independent assessment from a publicly procured panel of Technical and commercial specialists. Only applications which receive a positive recommendation from the external assessors will be recommended for support. It is envisaged that this will reduce the risk of lower quality applications being considered. A dedicated member of the Programme Delivery Team	

Table 10.1: Overview of the Co-Innovate Programme		
Strand	**Description, Anticipated Outputs and Targets**	**Expected Result**
	will be assigned to each successful application. This will ensure continuity through the assessment and delivery process. Programme staff will provide feedback decisions to all assessed applications, including those unsuccessful. Detailed Letters of Offer will be issued to successful partnerships in accordance with agreed corporate governance. All collaborative projects will commence with an initiation meeting to agree on the project plan and project meeting timetable. The assigned Programme Delivery Team member will attend and be the contact point for all project issues. This will mitigate the risk of project slippage. Project meetings will be conducted on a quarterly basis to ensure progress is on track, any potential hurdles are addressed, claims are submitted promptly and that a plan is in place for the next quarter. A formal record of the meeting will be undertaken and agreed by each partner. This will be recorded on the dedicated Information Management Portal. Companies that participate on a Co-Innovate Business to Business Partnership are suggested to expect the following benefits: • Development of new or improved innovative products or services; • Increased rate of commercialisation; • Sharing otherwise inaccessible knowledge, technology and expertise; • Access to complementary expertise, networks and channels through your innovation business partner; • Access to academic/consultancy support. Companies that participate on a Co-Innovate Cluster Partnership are suggested to expect the following benefits: • Access to a collaborative network and innovative research through cross-border/inter-regional and potentially transnational partners; • Access to complementary expertise, networks and channels through other cluster members including businesses, academics and consultants; • Increased ability to apply research and commercialise products. The Programme will fund: • €7,000 for a Consultant to write the Stage 2 application/Business Case; • Salary / Labour Costs; • Overheads; • Technical Consultancy / Contractual Research Costs; • Travel and subsistence; • Intellectual Property; • Equipment costs for prototyping equipment; • Materials costs in relation to developing prototypes; • Clinical Trials and Testing Costs.	

Ultimately, the project partners anticipate that the programme will create a unique cross-border innovation ecosystem and produce long-term benefits by establishing new contacts, sharing expertise and experiences, and developing solutions to common issues, leading to increased collaboration on R&I, across the entire region.

Seven work plans have been developed.

Table 10.2: Summary of Co-Innovate Project Work Plans (Per Progress Reports)	
1	Management
2	Strand 1 – Preparatory Interventions delivered via Workshop
3	Strand 2 – Preparatory Interventions delivered on a one-to-one basis
4	Strand 3 – Innovation Capability Development Programme
5	Strand 4 – Cross-Border Innovation Programme
6	Strand 5 – Cross-Border R&I projects
7	Communication

10.2.1 *Prospective Change in Co-Innovate Programme*

The Co-Innovate Project Partners have advised the Evaluation Team (at July 2019) that they have sought additional INTERREG funding from SEUPB.

According to the Project Partners, following discussions between SEUPB and lead partner InterTradeIreland, the possibility of additional funding being made available to the Co-Innovate programme should the partners be capable to utilise this in order to enhance the innovation capability development and Research and Innovation project support to the eligible SMEs engaged on the programme.

Consequently, the Project Partners developed a concept paper (dated January 2019) which outlines how the Co-Innovate Programme might utilise this additional funding.

Key aspects of this paper are summarised below:

- A constraint of the Co-Innovate Programme is suggested to be the relatively low percentage of SMEs that are anticipated to receive strand 3, 4 or 5 support in comparison to the original intake number at the workshop stage. The Programme partners consider there to be an opportunity to provide additional support to SMEs.
- In order to significantly increase the number of businesses that the programme can make a positive impact upon, the project partners have proposed to utilise the additional funding in order to achieve an uplift in numbers supported. Suggested changes are summarised below:

Strand 2: Business Status Reviews	In the initial development of Co-Innovate, it was proposed that 15% of those attending workshops would not take up the option to proceed to complete a Business Status Review (BSR). However, the project partners have found that, in reality, only c.2% of companies in NI/ROI that have attended workshops have indicated that they do not wish to undergo a Business Status Review. As at this point of the programme (having just completed an innovation workshop), there is little in-depth information gathered by the Co-Innovate Team on each business (as this is in advance of Business Status Reviews or Innovation Audits). Therefore, the project partners suggest that it is very difficult to make an informed judgement on the oversubscribed numbers wanting to progress on who should or should not be allowed to go forward. To ensure all participating companies have the same opportunity to have a BSR completed, the project partners have proposed that **an extra 140 BSR places** in Strand 2 for NI/ROI.
Strand 3: Innovation Capability Development through Mentoring	The project partners consider that the greatest opportunity for benefitting the most significant volume of businesses on the programme would be achieved as a result of uplifting the numbers in Strand 3 of the programme. They suggest that, in their experience of the programme, they have identified shortcomings in many businesses that would prevent or significantly impact their ability to successfully undertake R&I collaborative projects. Therefore, they have found that many businesses are not ready to even apply for strand 4 and 5 project

	support. The project partners consider that the intervention or mentoring and expert advice for innovation capability development that is offered in strand 3 is perfect for addressing these shortcomings, and in turn should assist in improving the quality of projects which apply for strand 4 and 5. In addition, the project partners report that SMEs that have engaged in the audits have identified this as an area they could benefit from expert guidance with as many they do not currently have this expertise in house. Most businesses do not have a separate innovation strategy to meet their corporate goals. The partnership considers that developing this with them would create a clear path for future innovation and help to leave a positive legacy for them to carry out internally in the future.

- The following tables outline the proposed uplift to the current (at July 2019) approved Co-Innovate Programme target numbers:

Table 10.3: Proposed Amended Strand 2 Targets Per Partner

	Original BSRs	New Additional BSRs Proposed	Total Proposed BSRs
NI (ITI)	595	91	**686**
RoI (ITI)	306	49	**355**
Scotland (SE)	150	0	**150**
Scotland (HIE)	149	0	**149**
Total	**1200**	**140**	**1340**

Table 10.4: Proposed Amended Strand 3 Targets Per Partner

	Original 10 Days Mentoring / Expert Advice	New Additional 10 Days Mentoring / Expert Advice
NI (ITI)	46	60
RoI (ITI)	24	60
Scotland (SE)	12	10
Scotland (HIE)	12	10
Total	**94**	**140**

- The Co-Innovate Programme has proposed that the cost associated with the proposed additional activity would be: €1,362,219.

10.3 Project Budget

The Co-Innovate project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €16,671,743.79 (ERDF + Government Match Funding) to be expended and claimed by 31st March 2022, towards total anticipated project costs of €22,443,035.35, as summarised in the tables below:

Table 10.5: Anticipated Project Costs

	Total
Staff costs	4,365,249.00
Office and administration	654,787.35
Travel and Accommodation	556,152.00
External expertise and services	16,730,179.00
Equipment	136,668.00
Total	**22,443,035.35**

Table 10.6: Project Funding

	Total
Cash Contribution (Partner Supplied / other grant)	5,771,291.56
Government Match Funding	1,969,241.65
ERDF	14,702,502.14
Total Grant Funding	**16,671,743.79**
Total Project Costs	**22,443,035.35**

The Letter of Offer notes that the period of assistance is for 67 months and 30 days starting on 1 August 2016 and completing on 31 March 2022 (the Project Lifetime).

It is noted that the above costs and sources of project income may be subject to change if the aforementioned additional funding is secured by the Co-Innovate Programme.

10.4 Anticipated Project Objectives, Outputs and Results

10.4.1 Objectives

The Co-Innovate project partners have outlined the following anticipated project outputs and targets:

Table 10.7: Anticipated Outputs	
Strand 1	• 108 workshops: 56 in Northern Ireland, 24 in Ireland, 28 in Scotland. • 1,408 participating SMEs: 696 in Northern Ireland, 360 in Ireland and 352 in Scotland)
Strand 2	• 1,200 business status reviews: 595 in Northern Ireland; 306 in Ireland; 299 in Scotland. • 469 innovation audits: 232 in Northern Ireland; 119 in Ireland; 118 in Scotland
Strand 3	• 94 SMEs completing the Capability Development Programme: 46 in Northern Ireland; 24 in Ireland; 24 in Scotland
Strand 4	• 70 graduates engaged in SMEs: 27 in Northern Ireland; 26 in Ireland; 17 in Scotland.
Strand 5	• 15 business partnerships investing in R&I activity and receiving grant assistance: 6 in Northern Ireland; 5 in Ireland; 4 in Scotland. • Network projects established: 2 in Northern Ireland; 1 in Ireland; 1 in Scotland. • 5 Research Agencies involved in partnership projects: 2 in Northern Ireland; 1 in Ireland; 2 in Scotland

<u>Strand 1 - Targets</u>

Table 10.8: Strand 1 Targets						
Year	**Northern Ireland**		**Ireland**		**Scotland**	
	Workshops	**SMEs**	**Workshops**	**SMEs**	**Workshops**	**SMEs**
2017	28	325	11	190	15	198
2018	18	255	7	100	11	134
2019	10	116	6	70	1	10
2020	0	0	0	0	1	10
Total	**56**	**696**	**24**	**360**	**28**	**352**

<u>Strand 2 - Targets</u>

Table 10.9: Strand 2 Targets						
Year	**Northern Ireland**		**Ireland**		**Scotland**	
	Business status reviews	**Innovation audits**	**Business status reviews**	**Innovation audits**	**Business status reviews**	**Innovation audits**
2017	242	76	149	38	168	49
2018	251	106	98	50	103	46
2019	99	48	59	28	20	18
2020	3	2	0	3	8	5
Total	**595**	**232**	**306**	**119**	**299**	**118**

<u>Strand 3 - Targets</u>

Table 10.10: Strand 3 Targets			
Year	**SMEs completing the Capability Development Programme**		
	Northern Ireland	**Ireland**	**Scotland**
2018	15	7	8
2019	18	10	9
2020	11	6	6
2021	2	1	1
Total	**46**	**24**	**24**

Strand 4 - Targets

Table 10.11: Strand 4 Targets			
Year	**Innovation graduates placed in SMEs**		
	Northern Ireland	**Ireland**	**Scotland**
2019	4	4	2
2020	13	13	9
2021	10	9	6
Total	**27**	**26**	**17**

Strand 5 - Targets

Table 10.12: Strand 5 Targets									
Year	**No. of Business Partnerships**			**No. of Network Projects**			**No. of Research Agencies Involved**		
	NI	**ROI**	**Scotland**	**NI**	**ROI**	**Scotland**	**NI**	**ROI**	**Scotland**
2019	2	2	1	-	-	-	-	-	-
2020	4	3	3	1	-	1	1	-	1
2021	-	-	-	1	1	-	1	1	1
	6	**5**	**4**	**2**	**1**	**1**	**2**	**1**	**2**

10.4.2 *Non-Monetary Benefits*

The project partners anticipate that SMEs participating in the Co-Innovate Programme will:

- Promote and stimulate a culture of R&I;
- Inject and embed sustainable innovation management practices;
- Create positive changes in market growth, jobs, wealth creation, investment in product development, and new products, processes and services;
- Invest more in human capital, leading to improved skills, productivity, performance, recruitment, staff retention and reduced absenteeism;
- Share knowledge and experience in R&I with other SMEs and with educational and research institutions;
- Promote open innovation and improve access to the innovation ecosystem across the eligible area;
- Avail of cross-border and inter-regional collaboration opportunities;
- Improve their capacity for sustainable development.

10.4.3 *Outputs and Results*

The Co-Innovate project's approved outputs (per its LoO, dated 21 June 2017) are as follows:

Table 10.13: Co-Innovate Outputs			
	Programme output indicators	**Programme output indicator targets**	**Project main output quantification (target)**
CO01	Productive Investment: Number of enterprises receiving support;	1,408	1,408
CO02	Productive Investment: Number of enterprises receiving grants;	19	30
CO04	Productive Investment: Number of enterprises receiving non-financial support	1,408	1,408
CO26	Research, Innovation: Number of enterprises cooperating with research institutions	50	50
CO41	Productive Investment: Number of enterprises participating in cross-border, transnational or interregional research Projects	19	30
CO42	Productive Investment: Number of research institutions participating in cross-border, transnational or interregional research projects	5	5
1.22	Number of enterprises receiving one-to-one innovation advice	469	469
1.23	Number of enterprises in receipt of an Innovation Capability Development Programme	94	94
1.24	Number of enterprises engaging an Innovation Intern	70	70

10.5 Contribution to the Priority's Specific Objectives and Result Indicators

This section considers the Co-Innovate project's key achievements (as of June 2019) and the extent to which the Co-Innovate project has:

- Contributed to the achievement of the Priority's Specific Objectives; and
- Contributed to the achievement of the targets for the Result Indicators.

The section also identifies any external factors that have impacted, positively or negatively, on the project's ability to contribute to the achievement of the Specific Objective.

10.5.1 Key Achievements (to June 2019)

Key achievements (at June 2019) by project strand are discussed below:

Strand 1

At June 2019, the Co-Innovate project partners had delivered 111 workshops, attended by 1,131 SMEs, as follows:

Table 10.14: Progress under Strand 1

Year	Northern Ireland		Ireland		Scotland	
	Workshops	SMEs	Workshops	SMEs	Workshops	SMEs
Business Plan Target (to 2020)	56	696	24	360	28	352
Actual (at June 2019)	53	523	25	318	33	290
Difference	**-3**	**-173**	**1**	**-42**	**5**	**-62**

The table illustrates that after 23 months, the project partners have recruited approximately 80% of the overall anticipated workshop attendees. Given that activity was originally envisaged to commence during January 2017, but started 6 months later in July 2017 (following permission to start being granted during mid-June 2017), this level of activity should be considered positively.

It is understood that all 1,131 businesses that attended the workshops completed ready reckoners;

Of the 1,131 businesses that attended the workshops, xx (xx%) lodged an expression of interest in progressing onto Strand 2

Strand 2 - Targets

- At June 2019, 784 businesses had completed a Business Status Review.
- 255 businesses completed an Innovation Audit (which commenced in February 2018).

Table 10.15: Progress under Strand 2

Year	Northern Ireland		Ireland		Scotland	
	Business status reviews	Innovation audits	Business status reviews	Innovation audits	Business status reviews	Innovation audits
Business Plan Target (to 2020)	595	232	306	119	299	118
Actual (at June 2019)	420	149	227	70	137	36
Difference	**-175**	**-83**	**-79**	**-49**	**-162**	**-82**

It is noted that HIE (Scotland) had been experiencing some difficulty compared to the other delivery partners in moving the businesses through the 2 assessment in Strand 2 as quickly. This was suggested to be due to the fragmented geography and complexity in travelling around this region taking additional time. As a result, SEUPB was asked to consider a proposal to utilise underspend in some areas and potential additional funding to utilise procured consultants from a HIE framework to deliver the Strand 2 assessments.

Strand 3 - Targets

At June 2019, 62 businesses were approved for Strand 3 support, against the final target 94. Of the 62 businesses 24 had completed their participation in Strand 3.

Table 10.16: Progress under Strand 3			
Year	**SMEs completing the Capability Development Programme**		
	Northern Ireland	**Ireland**	**Scotland**
Business Plan Target (to 2021)	46	24	24
Actual Approved (at June 2019)	38	13	11
Actual Completed (at June 2019)	14	5	5
Difference	**-32**	**-19**	**-19**

The Partners report that this Strand of support has proved to be extremely popular, and as a result, they were progressing through their allocated target numbers well ahead of schedule. As a result, the project partners submitted a paper to SEUPB requesting additional funding.

Strand 4 - Targets

By the end of June 2019, 11 business had been approved for support under Strand 4. Most of these businesses had also been approved for Strand 3 mentoring as well. The project partners indicate that most businesses preferred to complete Strand 3 before beginning the applications for Strand 4, in order to inform their Strand 4 application content and subsequent project work.

Table 10.17: Progress under Strand 4			
Year	**Innovation graduates placed in SMEs**		
	Northern Ireland	**Ireland**	**Scotland**
Business Plan Target	27	26	17
Approved to Start, but not yet started (at June 2019)	5	5	1
Actual Started (at June 2019)	0	0	0
Actual Completed (at June 2019)	0	0	0
Difference	**-27**	**-26**	**-17**

However, it is understood that (at June 2019) none of the 11 prospective projects had commenced, albeit each of the 11 businesses have been matched to their Academic Partners by Helix and Interface (Procured Academic Institute Management Agents for Ireland and Scotland respectively). In addition, the project partners have worked with (e.g. establishing their project potential and developing some of their academic partnerships and submissions) a further 19 businesses, only for them then to decide to place the project on hold or to exit the programme entirely. The project partners cite Brexit as being a key influence on this.

Encouragingly, the project partners report that they have (at June 2019) a further 35 projects in their pipeline “with reasonable potential” to progress to receive Strand 4 support.

The Project Partners note that Strand 4 and 5 activity is currently progressing at approximately 6 months behind schedule. According to the Project Partners, this 6 months is due to the final Letter of Offer and Permission to Start only being granted on the 21st of June 2017, and only at this point could the Enterprise Agencies and Recruiters be cleared to recruit companies for the programme delivery (recruitment was originally due to begin in January 2017). The project partners indicate that they have not yet been able to reduce the impact of the six-month delay on Strand 4 activity.

Strand 4 is anticipated to be completed by 31st December 2021. As each Strand 4 project is envisaged to be 12 months in duration, this indicates that each would need to have commenced by 31st December 2020 at the latest.

The Co-Innovate team have continued to liaise and meet with the academic institutes across the eligible region during to raise their awareness of the programme, their potential involvement and how they could become part of it.

Strand 5 - Targets

At June 2019, 6 business had been approved to receive Strand 5 Feasibility Study support. It is understood that all 6 have been approved for full Strand 5 support, but only 1 Business Partnership project has commenced.

Table 10.18: Progress under Strand 5

	No. of Business Partnerships			No. of Network Projects			No. of Research Agencies Involved		
	NI	ROI	Scotland	NI	ROI	Scotland	NI	ROI	Scotland
Business Plan Target	6	5	4	2	1	1	2	1	2
Feasibility Studies Approved (at June 2019)	2	2	0	1	0	1			
B-B/Cluster Projects Approved, but not yet started (at June 2019)	1	2	0	1	0	1			
Actual Started (at June 2019)	1	0	0	0	0	0			
Actual Completed (at June 2019)	0	0	0	0	0	0			
Difference									

The Innovation Expert (with responsibility for this Strand) had also been promoting the direct entry to this Strand of the programme and speaking with businesses who were interested in joining Co-Innovate this way and engaging in a potential R&I project with another or several other businesses.

Strand 5 is anticipated to be completed by 31st December 2021. As each Strand 5 project is envisaged to be 24 months in duration, this indicates that each would need to have commenced by 31st December 2019 at the latest.

Other

The Co-Innovate project partners also cite the project's key achievements (as of October 2018[114]as being:

Table 10.19: Other key project achievements

Period	Dates	Key Achievements
1	1st August 2016 – 31st October 2016	• In this first period of the Co-innovate Programme, the work activities focused entirely on developing the partner relations and agreements (e.g. realignment of budgets and cash flow projections, annual forecasts, operations timetables and targets, partnership agreements, procurement, monitoring plans, etc. • As the individual strands (work packages) of the programme were not scheduled to commence until July 2017, none of the project output deliverables or objective target numbers were met during this time period.
2	1st November 2016 – 31st January 2017	• Work began on creating the various procurement activities for interim innovation experts, sectoral workshop speakers, ROI company recruitment agents, MIS system, Business Status Review consultants, and Innovation Audit consultants.

[114] Please note that the other key achievements have been documented in respect to the most recent Project Progress reports that were available to the Evaluation Team at the time of writing.

Table 10.19: Other key project achievements		
Period	**Dates**	**Key Achievements**
		• Co-Innovate job descriptions were agreed, with the recruitment process beginning in the latter part of this period. In the interim, 2 key positions were covered by using an ITI employee seconded into the role of interim Programme Director, and procurement of services of Team BDS for the Innovation Expert role. Both needed in order to keep the progress and development of the programme on time. • Partners commenced discussions on the Ready Reckoner, Workshop Presentation and supporting documentation, Business Status review, and the Innovation Audit and supporting documentation, which form the basis of SME recruitment.
3	1st February 2017 – 30th April 2017	• The recruitment interviews and induction of the dedicated Co-Innovate team members was completed for all positions within ITI, SE and HIE. A suitable candidate for the Innovation Expert was not found on the 1st recruitment drive, so a 2nd recruitment exercise commenced in April 2017. • With Team BDS, the partners had input into the development of the Ready Reckoner document, Workshop content and supporting documentation, and the Innovation Audit and its supporting documentation.
4	1st May 2017 – 31st July 2017	• Strand 1 workshop format, presentations, ready reckoners, and material were developed with Team BDS and approved via the PMC. Training with partners was delivered. • Recruitment of SMEs began (148 businesses completed the Ready Reckoners) and the first 3 workshops were held (Downpatrick, Sligo and Letterkenny). • Recruitment drives for Co-Innovate Innovation Expert and Executive positions. • Procurement of Management Information System, Business Status Review Consultants, and Innovation Audit Consultants were underway and advanced with CPD. • State aid rationale for Co-Innovate developed and approved by PMC, DfE and SEUPB.
5	1st August 2017 – 31st October 2017	• Irish and Scottish launches on 7th and 18th of September. Heather Humphreys TD, Dr Andrew McCormick Permanent Secretary, and Michael Russell MSP were in attendance. • Scottish workshops started in September, delivered by both SE and HIE Co-Innovate Staff. • In period 5, NI and ROI: 15 workshops/260 attendees. SE: 4 workshops/41 attendees. HIE: 2 workshops/22 attendees. • The first 22 BSRs took place in Scotland by SE in October. • Innovation Expert headhunting approach was agreed with SEUPB.
6	1st November 2017 – 31st January 2018	• Workshops continued to be delivered by the Co-Innovate teams in ITI, SE and HIE. • Strand 2 Business Status Reviews continued. A panel made up of ITI, SE, CBLEP and HIE was set up to assess the progression of SMEs from BSR to IAs, which started in November 2017; • Strand 2 Innovation Audits commenced. • MIS went live on 23rd October and all partners began populating Strands 1 and 2. • Strand 3 Mentor Manager procurement was created, advertised and awarded to Helix Ireland for Ireland and Targeting Innovation for Scotland; • Strand 4 Procurement documents for Academic Institutes was developed with CPD to follow a similar approach to the strand 3 mentor manager.
7	1st February 2018 – 30th April 2018	• Workshops delivered to schedule. • Strand 2 BSR continued. • Strand 2 innovation audits began. • Strand 3 began in April 2018. CPD tender to procure the mentors was completed. Helix and Targeting Innovation were appointed as the mentor managers in Ireland and Scotland respectively.

Table 10.19: Other key project achievements		
Period	**Dates**	**Key Achievements**
8	1st May 2018 – 31st July 2018	• Workshop recruitment continued; • Strand 2 BSR and panel assessments continued; • Strand 2 innovation audits continued. A fortnightly panel assessed applications to progress from IAs to strands 3, 4 and 5; • CPD tender to manage the appointment of Academic Institutes for strand 4 projects were awarded to Helix Ireland and Interface Scotland; • The Partners found that most participants wished to complete their strand 3 mentoring in order to develop their capabilities to support the applications for Strands 4 and/or 5. • Co-Innovate was registered on the EU's SANI State Aid system; • The Partners submitted a paper for potential additional funds to uplift programme output numbers.
9	1st August 2018 – 31st October 2018	• Weekly panels assessed applications to progress from BSRs to IAs and IAs to Strands 3, 4 and 5; • Strand 4 launch event was held in IT Sligo; • Graduate Fairs were attended by ITI and SE teams in Dublin, Glasgow and Belfast to promote to Strand 4 interns.

10.5.2 *Progress towards the Project's Output Indicators*

Table 10.20 provides a high-level summary of the progress that has been made by the Co-Innovate project towards its Output Indicators.

Table 10.20: Progress towards the Co-Innovate Output Targets					
	Programme output indicators	**Programme Targets**	**Project Target**	**Achieved (At June 2019)**	**Variance against project target**
CO01	Productive Investment: Number of enterprises receiving support	1,408	1,408	1,131	-20%
CO02	Productive Investment: Number of enterprises receiving grants	19	30	0	-100%
CO04	Productive Investment: Number of enterprises receiving non-financial support	1,408	1,408	1,131	-20%
CO26	Research, Innovation: Number of enterprises cooperating with research institutions	50	50	0	-100%
CO41	Productive Investment: Number of enterprises participating in cross-border, transnational or interregional research projects	19	30	0	-100%
CO42	Productive Investment: Number of research institutions participating in cross-border, transnational or interregional research projects	5	5	0	-100%
1.22	Number of enterprises receiving one-to-one innovation advice	469	469	255	-46%
1.23	Number of enterprises in receipt of an Innovation Capability Development Programme	94	94	0	-100%
1.24	Number of enterprises engaging an Innovation Intern	70	70	62	-11%

In summary, the Co-Innovate project is progressing towards its project work plan and the Project Partners anticipate that more substantive progress will be made towards a number of the targets with the implementation of Strands 4 and 5 of the project (with businesses currently being assessed and approved under these activity strands).

10.5.3 *Target Groups Reached*

Table 10.21 provides an overview of the target groups reached as a result of the Project's activity to date. In summary monitoring materials provided by the Project Partners indicate that the Co-Innovate Programme has reached 80% of its target group.

Table 10.21: Target Groups Reached			
Target Groups	**Target Value**	**Target Groups Reached (at June 2019)**	**Target Groups Reached %**
SMEs	1,408	1,131	80%

10.5.4 *Progress towards the Project's Result Indicator Targets*

As noted in Section 1.3.3, the result indicator for the Co-Innovate project is to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from 22%[115] (2014) to 33% by 2023.

Per Section 2.3, the Evaluation Team has reservations in relation to the degree to which the target is 'achievable' and 'realistic' and notes that progress can only be measured in the longer term.

10.5.5 *Factors that have impacted on the achievement of the Project's Output and Result indicators and the Priority's Specific Objectives*

The Project Partnership advises that the project has encountered a number of issues in the delivery of the Co-Innovate project to date and uncertainty presently exists as to the potential impact of these issues on the overall achievement of the Project's Output and Result indicators and the Priority's Specific Objective. Specific issues cited by the Project's Partner include:

- **Uncertainty of 'Brexit' on business recruitment** - Consultation with the Project Partner's indicates that there have been delays in approving Strand 4 and 5 projects due to uncertainties that presently exist amongst the business community in the eligible region in relation to the potential impact of the UK's withdrawal from the EU (i.e. 'Brexit'). As noted previously, businesses participating in Strands 4 and 5 are required to contribute 50% of the total project costs. However, it is understood that a number of businesses have expressed reservations to commit funds and resources which may be required to address emerging needs following Brexit. It was suggested that this issue is more pronounced for those businesses that have engaged in relatively lower levels of Brexit planning/preparatory activities;

- **Delays in businesses progression along the Co-Innovate support funnel due to Strand 2 'bottlenecks'**- During consultation the Project Partners indicated that the requirement for businesses to complete two separate business assessment tools (i.e. a Business Status Review and Innovation Capability Audit), coupled with businesses' availability to engage in the support and provide the requisite information, had served to delay the progress of businesses through to subsequent strands of the Programme's support. Whilst it was anticipated that the process of a business' engagement in Strand 2 would take up to 4 weeks, the Project Partners note that the actual timeframes are between 6 and 8 weeks. In retrospect, the Project Partners suggested that it would have been beneficial to merge the two assessments into one in order to expedite the process and the bureaucracy placed on businesses;

[115] NB: To determine this baseline, SEUPB advised that specific questions were introduced into the January/February 2015 version of InterTradeIreland's quarterly All Ireland Business Monitor Survey. It is understood that 146 (22%, N=676) of the business respondents indicated that they undertook R&D&I and were supported by another organisation outside their own jurisdictions i.e. Northern Ireland, the border region of Ireland or Western Scotland. For the purposes of this paper (which focuses on cross-border collaborative R&D&I activity being between Northern Ireland and the border region of Ireland, excluding Scotland), SEUPB advised that 119 (22%, N=548) of the total business respondents based in either Northern Ireland (N=79) or border region of Ireland (N=40) indicated that they undertook R&D&I and were supported by another organisation outside their own jurisdictions i.e. Northern Ireland or the border region of Ireland.

- **Delivery of Programme activity in the Highland's and Island's area of the eligible region -** The Project's Partners note that levels of activity in the Highland's and Island's area is below that anticipated at the outset due to two interrelated reasons. Firstly, due to their peripheral location, the time required (up to three days) to engage with businesses located on the Scottish Island's on a face-to-face basis has taken longer than was anticipated at the outset. Secondly, and related to this point, it was initially anticipated that all strands of Programme activity would be delivered in the Highland's and Island's area by two Programme manager (as opposed to availing of external expertise to support programme delivery, as was being utilised in the other areas of the eligible region). However, in retrospect, the Project Partners suggest that the level of resource that was initially allocated was significantly below the level required to deliver the Programme within the stipulated timeframes. As such, it is understood that the Project Partners sought approval from SEUPB (and was subsequently granted approval) for the Programme to utilise external consultants to support the delivery of Strand 2 activity within the Highland's and Island's area;

- **Cross-border/transnational focus of support limiting engagement from some businesses -** Whilst noting the merits of the cross-border and transnational nature of the support, the Project Partners are of the view that the need for businesses to engage with academia (as part of Strands 4 and 5) on a cross-border/transnational basis creates geographical/logistical difficulties (perceived or actual) for some businesses, resulting in them unwilling to engage with the Programme, especially when other support mechanisms are available in their home jurisdiction which does not require them to take forward collaboration outside this jurisdiction;

- **Delays in financial claims being paid -** It was noted by the Project Partners that they have experienced delays in receiving payment for a number of financial claims that have been submitted to SEUPB. It was noted that this has inadvertently created delays in the payment of external expertise (e.g. mentors) who have subsequently expressed concern engaging with the Programme further.

10.6 Best Practice and Learning

This section considers whether the Co-Innovate project has resulted in any areas of best practice and learning.

Whilst noting that the Programme's structure and content is potentially too elongated (particularly at Strand 2), the Project Partners are of the view that the multifaceted 'umbrella' of support delivered through the Co-Innovate Programme is unique and offers the potential to take SMEs on a journey which will increase their knowledge and understanding of innovation, enhance their capability to engage in a collaborative project and ultimately de-risk their initial steps into undertaking a cross-border/transnational collaborative by contributing towards its financial costs. Linked to this it was noted that the 'funnel' approach and content of support has served to 'handhold' businesses through an unfamiliar environment and safeguard monies by ensuring that businesses are questioned and challenged at each strand of support.

10.7 Synergies between Projects funded

Whilst the Project Partners note that it has attended a number of SEUPB-facilitated events/information days with the management teams of the other INTERREG VA Priority 1 projects, to date it suggests that there have not been any overt synergies between the projects largely due to the fact that the seven projects funded under Specific Objective 1 are supporting activities focusing on earlier Technology Readiness levels (i.e. on undertaking research in the R&D&I continuum) whereas the Co-Innovate Programme is more overtly focused on supporting projects which are at higher TRLs and closer to the market (i.e. on undertaking innovation in the R&D&I continuum).

Notwithstanding this, the Project Partners suggest that the support delivered to date (i.e. under Strands 1 to 3) have served to increase businesses' preparedness to engage in other collaborative R&I supports, both within and across jurisdictions, on the innovation escalator. Indeed, as noted, businesses that did not proceed onto further strands of support have been signposted to other R&I supports which are deemed to be more relevant for their stage of development.

10.8 Effectiveness of the Cross-Border Collaboration and Partnership Working

This section considers aspects of the Co-Innovate project's collaborative and partnership working including:

- The effectiveness and added value of the Co-Innovate project's cross border collaboration in relation to the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project.

The project partners consider the project to represent *"an unprecedented cross-border partnership, made up of key local, regional, cross-border and national economic development agencies that bring unparalleled outreach to the SME community across the entire eligible region and extensive experience of delivering R&I programmes for SMEs that enhance the competitive capability of their regions".* The project partners believe that the tri-regional Partnership will ensure that the proposed results and outputs will be achieved on a strategic and comprehensive cross-border basis.

The partnership believes that the specific status and mandates of the partners enhance the opportunity to mobilise and engage key players in the innovation ecosystem to ensure that participating SMEs get access to the very best expertise available across the eligible area irrespective of their location.

The added value of this tri-regional partnership lies in the coming together of each partner's unique expertise and experience. This covers critically relevant areas including:

- Cross-border collaboration;
- Local knowledge;
- Innovation programme management;
- Knowledge transfer;
- SME engagement and development;
- Export development;
- Contacts and outreach with key local stakeholders;
- Delivery of EU funded programmes.

which will all be required to ensure the project achieves an increase in research and innovation collaboration and generates maximum impact across the region.

The partnership has also applied the principles of joint development, implementation, financing and/or staffing as follows:

Joint development:	In designing the Co-Innovate project, each of the partners have contributed their ideas and priorities on the basis of the particular challenges faced by businesses in their regions. Furthermore, they have jointly decided on the project activities, responsibilities, budget and management structure.
Joint implementation:	The Co-Innovate project has been designed so all partners have a strategic oversight role along with an operational role. All partners have agreed their respective contribution to the delivery of project outputs with activities and targets clearly assigned. A Steering Committee, comprising members from each partner organisation, has been established and meets quarterly to ensure that planned activities are carried out, milestones are met and unexpected challenges to implementation are dealt with.
Joint staffing:	A project management team, employed by the Co-Innovate lead partner, oversees the delivery of the programme. Each project partner has defined roles across each of the programme strands and has appointed staff to fulfil this role. Partner staff members will coordinate their activities with others involved in the strand, exchange information regularly and report into the project management team. The project partners consider that the development of a joint management structure will facilitate the building of new policy contacts, sharing of expertise and experiences and the development of a shared solution to common issues.

Joint financing:	Match funding has been agreed from the governments of Ireland, Northern Ireland and by the Enterprise Agencies of Scotland, illustrating their confidence in the partnership. The project has a single overall budget which will be disbursed to partners on the basis of activities undertaken. ITI, as lead partner, has responsibility for the administration and distribution of funds and reporting on their use.

10.9 Impact on Business and Industry

This section considers the impact made by the Co-Innovate project on business and industry within the eligible region.

As part of the research process the Evaluation Team undertook an online survey and telephone consultations with 267 businesses that received support through one or more of the first three strands of support delivered by the Co-Innovate Programme (i.e. Strand 1: Innovation Workshop, Strand 2: Capability Review/Business Assessments and Strand 3: Innovation Capability Development (Mentoring) support)[116].

Table 10.22 an overview of the profile of recipients of support and respondents by location.

Table 10.22: Profile of Recipients of Support and Survey Respondents

Strand of Support received:	Population (Recipients of Support)				Sample (Survey Respondents)			
	N=	NI	ROI	Scotland	N=	NI	ROI	Scotland
Strand 1	1,256	49%	29%	22%	267	51%	29%	20%
Strand 2 (BSR)	829	53%	35%	12%	207	53%	32%	15%
Strand 2 (IA)	238	52%	32%	16%	79	59%	27%	14%
Strand 3	80	70%	15%	15%	20	65%	10%	25%

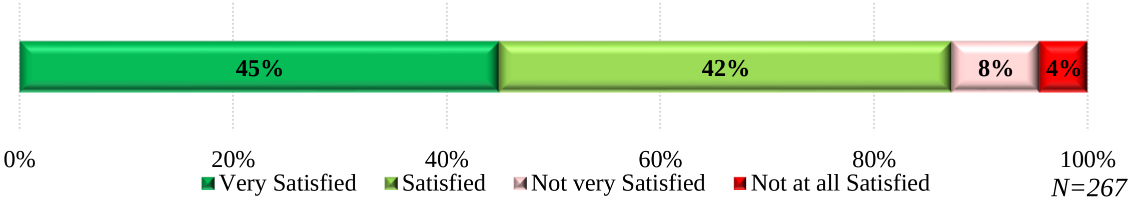
A summary of the feedback derived from businesses in receipt of the Co-Innovate support is detailed in the succeeding paragraphs. Whilst noting that the focus of the current evaluation is on assessing the impact of the support (as opposed to the efficacy of its implementation), the Evaluation has also sought to garner (at a high-level) businesses' views of, and satisfaction with, the support received.

10.9.1 Strand 1: Innovation Workshop

As part of their engagement on the Co-Innovate Programme, eligible businesses attended a half-day workshop which sought to enhance their understanding of (inter alia) innovation and how it can be embedded to benefit the business. The workshop also provided opportunities for the business to network with other local and cross-border businesses and develop an understanding of how other businesses have benefited from their engagement on the Co-Innovate Programme.

Encouragingly, nearly all respondents (87%, N=267) indicated that they were either 'satisfied' (42%) or 'very satisfied' (45%) with the support that was delivered during the innovation workshop. Specific areas in which respondents expressed particular satisfaction included the duration, structure and content of the workshops, the quality of the supporting materials, the calibre of the presenter and the opportunities to network with like-minded businesses.

Figure 10.2 Satisfaction with the support provided during the Innovation Workshop Strand



[116] Please note that the Co-Innovate Programme is currently approving innovation projects to be supported under Strands Four and Five of the Programme and hence these areas were not considered within the primary research. Given the scale of the population of businesses receiving support to date (N=1,256), provides a confidence interval of +/-5% at a confidence level of 95%.

Conversely, businesses that indicated that they were dissatisfied with the support that was provided (12%, N=267) suggested that (inter alia):

- The content of the workshop was not appropriately 'pitched' for the business' stage of development and/or the sector in which they operated (N=7);
- The content of the workshop was too high-level/generalised (N=5);
- The content of the workshop was too overtly focused on providing information on the support available through subsequent stages of the Co-Innovate Programme (N=4);
- Insufficient time was given to participants to network (N=4);
- Insufficient time was given to the questions and answers element of the workshop (N=3);
- There was a lack of engagement/communication following their participation on the workshop.

"As a new business taking its first steps into innovation, I thought the workshop was very informative and helpful."

"It was a good all-round introduction to what innovation is and how it can help businesses to grow. The content was clear and well-structured and I thought that the facilitator was knowledgeable about the subject area."

"It was a good informative session with other people and businesses I wouldn't normally be in a room with. However, there was no follow-up engagement."

"Overall I was happy with the workshop. It provided some useful insights and I was able to talk to some other businesses that had successfully engaged in innovation activities including how it had helped their business."

"It was a good refresher course for me. It was well structured, in a good location and didn't take too long. Some good real-world examples were discussed as well."

"The workshop was promoting a programme for well-established profitable businesses, but we are a start-up, so the programme was not for us."

"The majority of what was discussed was not relevant to all participants. There was too much focus placed on Research & Development."

"The workshop was just a pitch for Co-Innovate, it didn't really increase our knowledge of innovation. Similarly, the topics covered were too general; it needed to get down to specifics. There were also too many wordy charts and insufficient time for interaction either with the presenter or other businesses in attendance."

"Principles, Theory, Execution. We found a lot of the information good but vague and already available in the market or in general business knowledge. I think 90% of the attendees outlined that they were there to increase sales, however, this is stated as not the support or goal. The next level is also vague except for the fact that it is outlined as for larger businesses and includes investment that would be out of our reach. So, we end up not really sure about the efficacy or the next level of development from the support to date. The support did not develop or help to increase creative thinking for product or process. The Test Case presented to us was done so extremely professional and was a great story, but it failed to correlate or reach a bridge to what could be done in our business as it was a very well financially backed business. I feel that there should be a separation for smaller businesses and benefits for small, emerging and disruptive business to encourage real grassroots innovation."

"I feel the word and concept of innovation within the business was not articulated well. Also, my reading of how 'Innovation' is being framed and support is being given does not enable for social innovation or appear on the face of it particularly helpful to a culture of inclusion, which I think is a missed economic development opportunity."

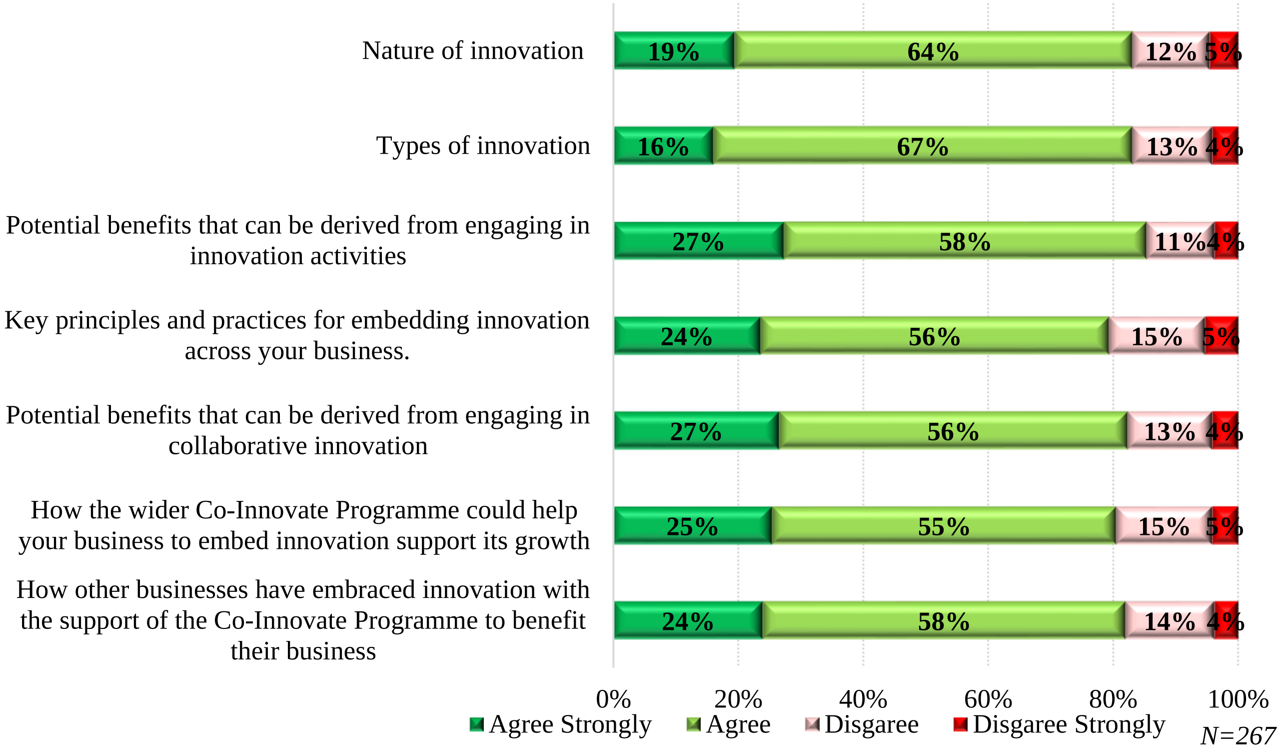
Strand 1 Innovation Workshop Attendees

Most (80%+, N=267) businesses were in agreement that their participation on Innovation Workshop had served to increase their knowledge and understanding of the:

- Nature of Innovation (i.e. what innovation is and is not) (83%, N=267);
- Types of innovation (83%, N=267);

- Potential benefits that can be derived from engaging in innovation activities (85%, N=267) and collaborative innovation e.g. with another business and/or academic institution (83%, N=267);
- Key principles and practices for embedding innovation across the business (e.g. Innovation Strategy & Vision, Knowledge Management & Technology, Ideation, Project Development, Commercialisation, Skills leadership and culture) (80%, N=267);
- How the wider Co-Innovate Programme could help the business to embed innovation support its growth (80%, N=267); and
- How other businesses have embraced innovation with the support of the Co-Innovate Programme to benefit their business (e.g. through the use of case studies during the workshop and/or the networking opportunities provided at the workshop) (82%, N=267).

Figure 10.3: Extent attendees agreed that the innovation workshop has increased their business knowledge and understanding of the following concepts



"I have definitely increased my understanding of the nature and importance of innovation in helping me to realise my business' growth plans."

"Initially, I thought innovation was solely about developing a new product that could be sold but it's actually about so much more. As a recent start-up with little experience in the area, I feel that I really developed my understanding and knowledge of how implementing these practices can help my top and bottom line."

"Like many businesses, we have been historically taking forward innovation activities on our own. I think there is always a bit of a fear factor around sharing your ideas in case you lose your competitive advantage. However, the workshop made the benefits of collaborating with others, whether they be other businesses or academia, very clear".

"Whilst it was maybe more pitched for first-time innovators, the information provided did increase our knowledge of the key principles and practices for embedding innovation."

"The workshop illustrated how innovation should become part of our 'day-in, day-out' activities."

"The workshop just gave us the push to move forward with a new innovation project."

Strand 1 Innovation Workshop Attendees

However, a sizeable cohort of businesses (of circa 20%) indicated that the Workshop that they had attended had not served to increase their knowledge and understanding of the:

- Key principles and practices for embedding innovation across the business (20%, N=267);
- How the wider Co-Innovate Programme could help the business to embed innovation support its growth (20%, N=267);
- How other businesses have embraced innovation with the support of the Co-Innovate Programme to benefit their business (18%, N=267); and
- Potential benefits that can be derived from engaging in innovation activities (17%, N=267).

"To be honest, the Workshop didn't tell me anything I didn't already know…it was all too theoretical and high-level…there was not 'innovation' brought to an innovation workshop."

"It felt like a sales pitch for the programme rather than the first steps on an innovation journey. Also, there didn't seem to be a pathway for my type of business, the support just stopped."

"It turned out that we are not large enough for the programme, so no support was offered. The workshop alone provides very little support. There should have been different programmes to suit different types of businesses."

"My business has been innovative since day 1 so we didn't require education on the subject."

Strand 1 Innovation Workshop Attendees

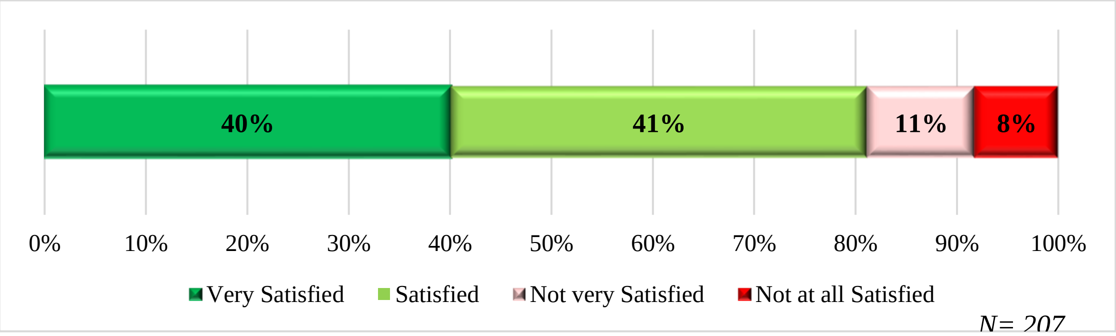
10.9.2 *Strand 2: Capability Review / Business Assessments*

As noted previously, businesses deemed to be eligible for further support through the Co-Innovate Programme were then provided with an opportunity to received support through the Capability Review Strand of the Programme. As part of this Strand of the Programme, businesses received:

- A Business Status Review (BSR)/Health Check with an experienced business advisor to identify if the appropriate foundations are in place within the business to support innovation activity. The support culminated in the business receiving a tailored Action Plan; and (where deemed eligible); and
- An Innovation Capability Audit (ICA) with an experienced Innovation Consultant which provide a detailed analysis of the business' innovation capabilities, reviewed potential research & innovation projects opportunities and provided tailored advice and guidance on how to develop their R&I capability and growth potential further in line with the business' growth plan.

Just over four-fifths (81%, N=207) of business indicated that they were either 'satisfied' (44%) or 'very satisfied' (42%) with the support that was provided during the Capability Review strand of the Co-Innovate Programme.

Figure 10.4: Satisfaction with the support provided during the Capability Review Strand



"The whole process was very thorough and professional. The advisor took the time to understand the business, its innovation needs, and the barriers that were inhibiting us from embedding innovative practices more fully than we currently are."

"The Assessments considered a diverse range of business areas and were very useful in seeing how we were performing…the results were a great boost to all the staff and really focused minds in terms of our next steps."

"We were very happy with the assessments. They served to provide us with a good 'stock-take' of where we are currently sitting. It's good to hear where you are doing well whilst also identifying the areas that you need to focus on to help the business grow."

"The person that undertook the assessments was very good. They covered a range of areas within the business and provided feedback to us in a timely manner. We are still in contact with the Advisor and they are providing some additional support to us."

Strand 2 Capability Review Assessment recipients of support

Key reasons as to why businesses that expressed dissatisfaction with this element of the support (19%, N=207) included:

- The process for completing the Capability Review Assessments was overly bureaucratic and took too long to complete (N=14);
- The advice provided by the Innovation Consultant (undertaking the Innovation Audit) was overly generic and not tailored to the needs and focus of the business (N=12).
- There was an excessive time period between undertaking the assessments and receiving any feedback (N=11). Indeed, a small number of businesses (N=5) indicated that they had not yet received any feedback from the Innovation Consultant that undertook the Assessments despite the fact that a number of months had passed since their engagement with the business.

"Businesses just don't have the time to spend all day collating so much information and answering questions that appeared to be of little relevance…the whole process just took far too long with little benefit on the flip-side."

"Having been asked so many questions we got very little in return and what we did get took a very long time. We were really disappointed by the process."

"I didn't understand the goal of Strand 2. I was the one being asked questions and we didn't receive anything in return."

"When we received the feedback, we questioned as to whether it related to another business. It was clear that the Consultant didn't understand our business, its performance and the issues that were affecting us despite spending hours going through it."

"The feedback could have been for any business. The support after the programme has been lacking, information that was promised to be passed on has not been - this has stalled progress."

Strand 2 Capability Review Assessment recipients of support

The majority (70%+, N=207) of the respondents agreed that the BSR has increased the business' knowledge and understanding of the:

- Specific areas of the business which are performing well (i.e. its key strengths) (73%, N=207);
- Specific areas of the business which are under-performing (i.e. its key weaknesses) (72%, N=207);
- Actions that could potentially be undertaken to address any weaknesses that were identified during the Business Status Review (72%, N=207); and
- Potential opportunities that exist to develop the business' innovation capabilities (70%, N=207).

However, potentially reflecting a level of dissatisfaction amongst some businesses in relation to the support received through the Capability Assessments, a relatively smaller but significant cohort of businesses (of circa 30%) suggested that they had not derived the benefits anticipated from undertaking the Business Status Review.

"We got some good feedback as to the general strengths and weaknesses of the business and importantly, what we need to do to address these weaknesses."

"The BSR was broadly useful to make sure that the business is progressing as it should be doing."

"We received a very clear outline of areas where we need to take action to expand our business."

"There was nothing particularly strong or directly helpful. I provided all the info so no new insights."

"The business review was a waste of time. It didn't tell us anything we didn't already know and the person doing it didn't add any value."

Strand 2 BSR recipients of support

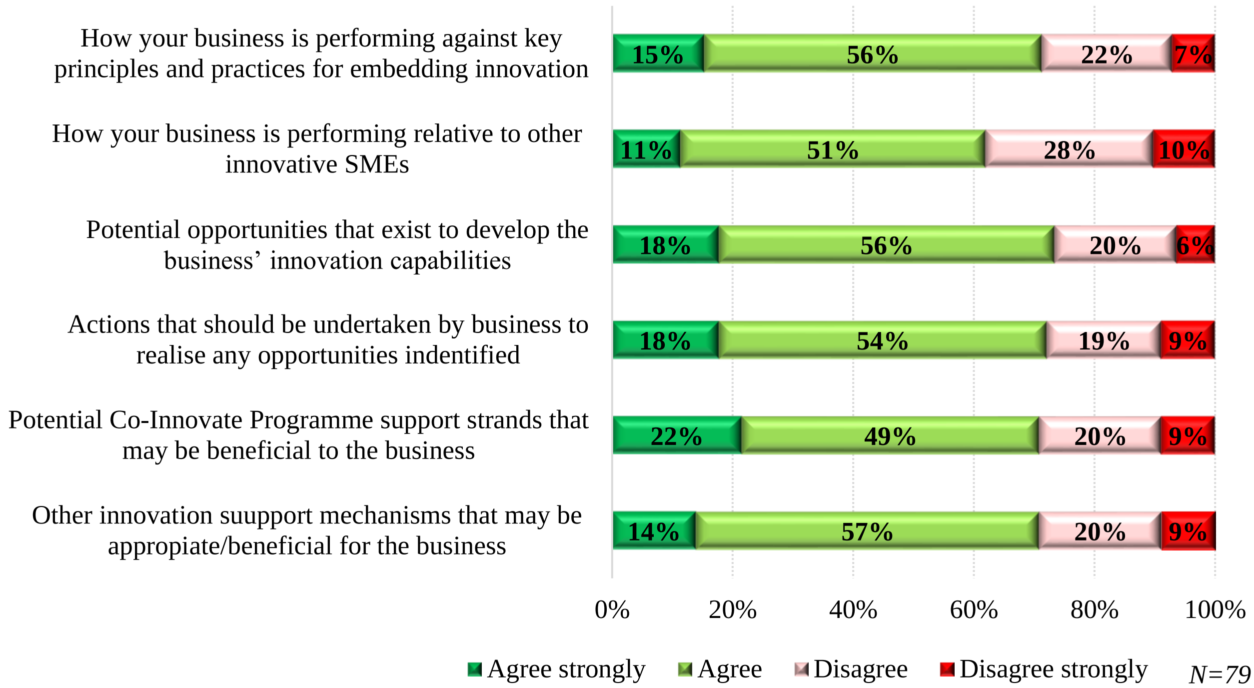
The majority (62%+, N=79) of the respondents agreed that the ICA had increased the business' knowledge and understanding of:

- How the business is performing against key principles and practices deemed to be of importance for embedding innovation (e.g. Innovation Strategy & Vision, Knowledge Management & Technology, Ideation, Project Development, Commercialisation, Skills leadership and culture) (71%, N=79);
- How the business is performing relative to other innovative SMEs (62%, N=79);
- Potential opportunities that exist to develop the business' innovation capabilities (74%, N=79);
- Actions that should be undertaken by the business to realise any opportunities that have been identified (72%, N=79);
- Potential Co-Innovate Programme support strands that may be beneficial to the business (71%, N=79); and
- Other innovation support mechanisms that may be appropriate/beneficial for the business (if further support through Co-Innovate was not deemed to be appropriate) (71%, N=79).

The Evaluation Team again notes that there was a sizeable minority of business respondents that indicated that they had not derived the benefits that were anticipated from completing the ICA. Most notably:

- More than one-third (38%, N=79) of businesses suggested that the support had not increased their understanding of how their business is performing relative to other innovative SMEs;
- 29% of business suggested that they had not increased their understanding as to how their business is performing against the key principles and practices for embedding innovation and/or the potential Co-Innovate Programme Strands that might be beneficial to the business; and
- Over one-quarter of businesses suggested that the support had not increased their understanding of the potential opportunities that exist to develop the business' innovation capabilities and/or the actions that should be taken to realise any opportunities identified.

Figure 10.5: Extent attendees agreed that the Innovation Capability Audit has increased their business knowledge and understanding of the following concepts



N=79

"We now have a better understanding of how we are performing in relation to those innovation principles and practices that are deemed to be good practice."

"The Innovation Audit Capability has certainly assisted our business to examine how we are performing against other innovative SMEs and to look at developing potential opportunities."

"It was really beneficial to see how we are performing both in isolation and relative to others. Whilst we might not receive the financial support that is available through the other strands of the programme, we were signposted to a number of other InterTradeIreland and Invest NI Programmes that will potentially be of benefit to us."

"No real opportunities of solutions were provided, nor are we any clearer as to how we are performing against other businesses. For a process that took a considerable amount of time, I was really disappointed with the outputs."

"We were given conflicting information about the Programme on three occasions. The Programme was not suitable for pre-revenue start-ups irrespective of the quality of innovation and the size of the market. We were surprised at the lack of knowledge of key innovation concepts such as TRLs (Technology Readiness Levels). The Programme used up valuable time which I just don't have."

"There was no improvement, we were not told anything that we did not already know."

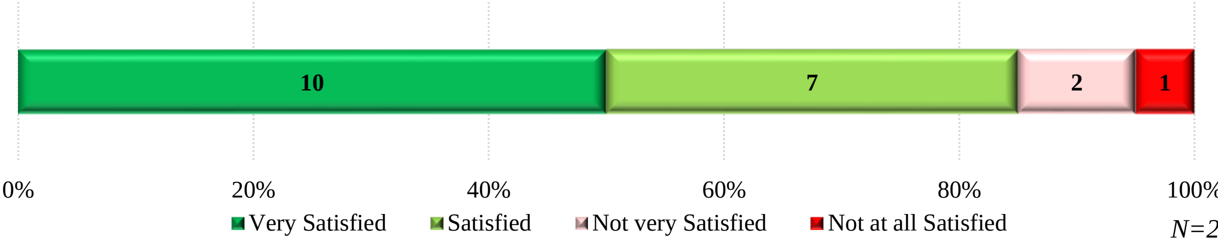
Strand 2 ICA recipients of support

10.9.3 Strand 3: Innovation Capability Development (Mentoring) Support

As noted previously, based on the developmental areas identified during the Capability Review stage, eligible businesses were able to receive up to 10 days one-to-one mentoring support, over a five-month period, to address specific challenges that were identified and enhance the business' overall innovation capabilities.

Encouragingly, the majority of respondents (17 of 20 businesses[117]) indicated that they were either satisfied (7 businesses) or very satisfied (10 businesses) with the support they received during the Innovation Capability Development support.

Figure 10.6: Satisfaction with the support provided during the Mentoring support



N=20

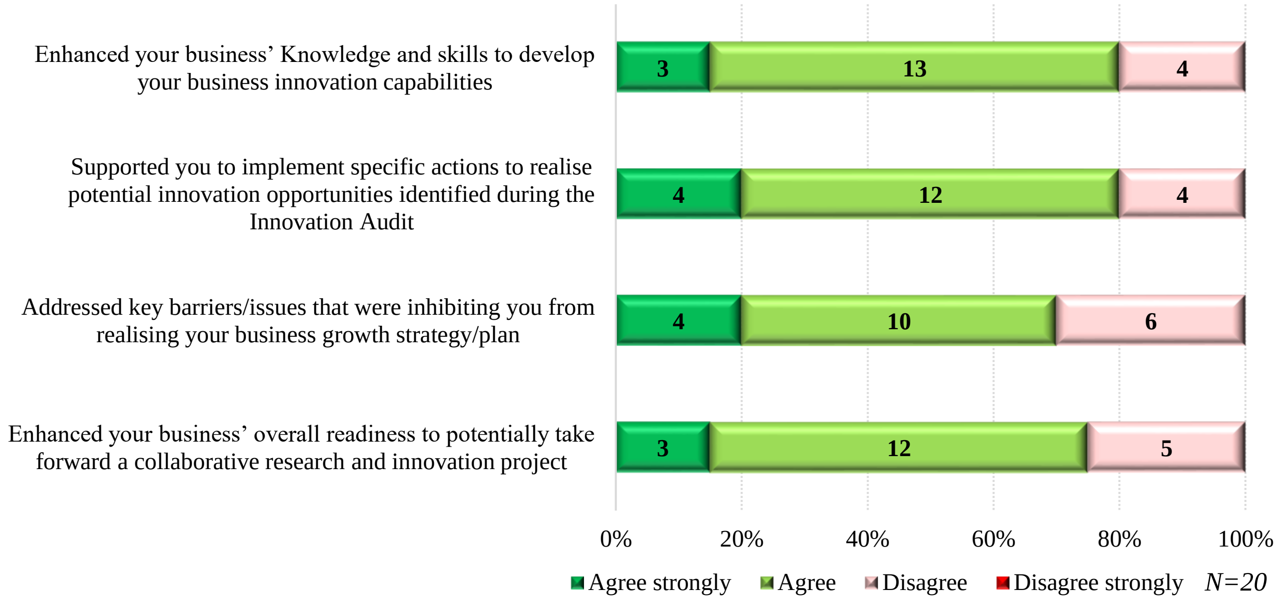
"We received excellent mentoring support. Very rarely to do we get a consultant who understands the complexities of our business model and can provide the strategic added-value that we need." *"The mentor was knowledgeable about the sector my business operated in and had clearly done some background research on the company before coming out. This meant that we could hit the ground running and use the time we had effectively."* *"I was very happy with the support received. Whilst I was a bit sceptical of the benefit that this element of the support would bring, I was pleasantly surprised. The mentor was able to provide advice that tailored to the needs of the business and we are already taking forward some of the recommendations that were provided during the sessions."* *"We invested time and effort and received nothing in return. We got through to phase 3 and were recommended for phase 4 and 5 but didn't get accepted. The first three phases were incredibly time demanding. We gave ourselves but in exchange, there was no benefits or support offered. I calculate that I wasted 2 workdays between attending the workshop and the consultants who came to my office to interview us. Each interview took around 3 hours, and despite being perfect candidates according to them for the following phases which do offer assistance, in the end, we received nothing for our efforts. There was no benefit for us whatsoever. We also received an email accepting us onto Phase 4 of the programme but then our contact said the email had been sent in error. Overall it was a very frustrating experience."* **Strand 3 Innovation Capability Development recipients of support**

The majority of the respondents were in agreement that the mentoring support had served to:

- Enhance their knowledge and skills to develop business innovation capabilities (16 of 20 businesses).
- Support the business to implement specific actions to realise potential innovation opportunities that were identified during the Innovation Audit (16 of 20 businesses);
- Enhanced the business' overall readiness to potentially take forward a collaborative research and innovation project (14 of 20 businesses); and
- Addressed key barriers/issues that were inhibiting the business from realising the business growth strategy/plan (15 of 20 businesses).

[117] Caution should be taken when interpreting the findings given the small sample size.

Figure 10.7: Extent attendees agreed that the mentoring support has increased their business knowledge and understanding of the following concepts



However, once again there was a sizeable minority of businesses that indicated that they had not derived the benefits that were anticipated during this stage of the Programme. For example, 6 of the 20 businesses indicated that the mentoring had not served to addressed key barriers/issues that were inhibiting the business from realising the business growth strategy/plan and 5 businesses suggested that the support had not enhanced the business' overall readiness to potentially take forward a collaborative research and innovation project.

"The engagement has kept us pursuing the innovation aspects of the business which we may have neglected whilst we concentrated on the day-to-day operation of the business. For us, the entire process has been hugely impactful."

"Together we identified three or four actions that the business had to implement to enhance our internal processes and approach to innovation. Whilst we are continuing to work on these, so far we have made good progress and are starting to see some efficiencies from the changes that we have made."

"As a result of the support received, I think we have a greater understanding of where we are at, where we want to get to and the steps we need to take to get there. I'm hopeful that having made the changes that we will see positive results in terms of business' performance."

"The support has helped us put processes in place to manage our innovation projects and workload better."

"Every aspect was beneficial. The opportunity for growth is there, but I have not acted yet. Plenty of advice was given."

"The mentor was able to draw on her experience of working with similar businesses within the manufacturing sector and provide some useful insights as to how we could improve our manufacturing processes. It was really useful advice and we are continuing to work with her on other matters."

"The advice provided was completely irrelevant and no proper support was provided. Some ideas were given but they had no idea about the industry that I work in, therefore the advice was irrelevant."

"The programme needs to go back to the drawing board and be completely reorganised. It was a waste of time and a poor structure."

"Whilst the mentor took the time to understand the issues facing the business, very little advice was given the address the issues."

Strand 3 Innovation Capability Development recipients of support

10.9.4 Summary Conclusions

The preceding analysis indicates that the majority of businesses in receipt of Strands 1 to 3 of support through the Co-Innovate Programme are satisfied with the support that they received and, importantly, have realised the knowledge and capability developments that were envisaged under each strand of support. Of note, the majority of businesses indicated that they have enhanced their knowledge and understanding of:

- The key concepts, practices and principles of innovation, as well as the potential benefits that can be derived from engaging in collaborative innovation;
- How their business is performing relative to other innovative SMEs; and
- The issues that are inhibiting their growth and associated opportunities/actions for development and are taking measures forward to address these issues.

Furthermore, the majority of businesses indicated that they have increased their readiness to ultimately take forward a collaborative R&D project.

Notwithstanding the largely positive feedback received, the Evaluation Team does however note that there was a sizeable minority of businesses that indicated that they were not satisfied with the support that they had received, with frequently raised concerns by this cohort including that they felt the support was too high level and generic, not tailored to the specific needs of the business, there were delays in receiving the outputs from the support and, linked to this, communication around receipt of information and their progress on the programme more generally could have been more effective. Consequently, these businesses indicated that they had not derived aspects of the benefits that were anticipated to be achieved from their participation on the Programme. It appears that these issues are most pronounced in relation to Stage 2 of the Co-Innovate Programme.

Whilst noting that levels of activity are, at this juncture, largely completed for the initial Strands of the Co-Innovate Programme, the Project Promoter should be mindful of the feedback received and seek to address (as far as possible) the issues that have been identified by recipients of support.

10.10 Contribution of the Project to Policy Objectives

This Section considers the contribution of the Renewable Engine project to key policy objectives in the eligible region. In doing so the section considers the project's contribution to:

- EU 2020 objectives;
- The Atlantic Strategy;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

10.10.1 EU2020 Objectives

It is the Evaluation Team's view that the Co-Innovate Programme offers the potential to contribute to a number of key objectives under the Europe 2020 Strategy including:

- 3% of the EU's GDP should be invested in R&D; and
- Ensuring that 75% of the population aged 20 to 64 should be employed.

10.10.2 The Atlantic Strategy

The Co-Innovate project does not offer the potential to directly contribute to the aims and objectives of the Atlantic Strategy.

10.10.3 The Horizontal Principals

The Co-Innovate project partners anticipate that the Programme will serve to contribute (at least in part) to the EU's three Horizontal Principals, per the following discussion:

<table>
<tr><td>Sustainable development</td><td>According to the project partners, the programme will, through its design, structure and outputs, positively impact on the three pillars of sustainable development, as follows:

• Social equity and cohesion – The programme is availing of existing agency structures in Northern Ireland and Ireland (such as the Local Enterprise Offices and the Enterprise Agencies) to ensure that the programme is promoted throughout the eligible areas in equal measure. The project partners believe that with relevant SME participation and a democratic approach to selection, this will benefit local communities in these areas in terms of wealth creation, job creation and investment in human capital.
• Economic prosperity – The programme seeks to direct dedicated R&I activities and knowledge transfer to businesses in the eligible region and to create enhanced research networks in areas of historical underdevelopment; and
• Environmental protection - The programme will actively encourage innovative approaches by prioritising enterprises and research institutes from the renewable energy sector, as well as projects dealing with renewable energy originating from other sectors.

The project partners have advised that all three aspects will be monitored and evaluated in line with targets and criteria set out for the programme (see section 10.2).</td></tr>
<tr><td>Equal opportunities and non-discrimination</td><td rowspan="2">Each of the key partners is a designated public body bound by relevant equality legislation and are fully supportive and experienced in the principle of mainstreaming equality.

The project partners advise that equality has been embedded in the development of the programme, through the adoption of tried and tested approaches for assessing and promoting equality, based on models developed by InterTradeIreland for all of its existing programmes and policies. This includes targeted activity to ensure balanced participation by men and women, by local Protestant and Catholic communities in Northern Ireland, and by persons with disabilities.

It is noted also that an initial equality screening of the programme was carried out at its proposal stage in accordance with the model specified for mainstreaming by the Equality Commission for Northern Ireland. Key features of the programme, including workshop/event management, graduate placement and communications, have also previously undergone formal Equality Impact Assessments (EQIAs[118]) to determine any impact they might have on the Section 75 categories. These involved widespread consultations with over 150 stakeholders, including Disability Action, Age NI and Women's Forum NI.

The initial screening and EQIAs did not identify any likely adverse impact from the proposed activity on people of different religious belief, political opinion or gender. Whilst it is noted that some communities or demographics may traditionally have been over-represented in some economic sectors (for example, men in research and innovation generally, Protestants/Unionists in engineering, biotechnology and pharmaceuticals), the programme will not, in itself, disadvantage any group.

The initial screening also identified that there may be some scope for older people, disabled people, carers and more marginalised ethnic groups to benefit from the overall objective of reducing poverty and promoting social inclusion by enhanced targeting of R&I activity.</td></tr>
<tr><td>Equality between men and women</td></tr>
</table>

118 An equality impact assessment (EQIA) is a thorough and systematic analysis of a policy to, determine the extent of any impact of a policy upon the Section 75 categories and to determine if the impact is an adverse one.

	No potential adverse effect was identified for persons of different marital status or sexual orientation. The screening also suggested that the programme may promote good relations between people of different religious belief, political opinion and racial grouping, by bringing together individuals from different jurisdictions, institutions and backgrounds to share knowledge and experience. It is anticipated that this blending of diversity is likely to break down established barriers to co-operation and enhance learning for competitive advantage.

10.10.4 Contribution to Other Strategies

The Co-Innovate programme aims to deliver supports for innovation that enhance the broad innovation ecosystem while focusing in particular on four key areas of sectoral specialism where enhanced innovation capabilities will benefit SMEs in the target region. As such, the project partners are of the view that the programme will contribute to a number of policy papers and strategies including:

- Ireland's 'Enterprise 2025: Innovative, Agile, Connected' National Enterprise Policy 2015-2025, which sets out the longer-term ambition for enterprise growth and job creation over the 10-year period. The Enterprise 2025 vision is for Ireland to be the best place to succeed in business, delivering sustainable employment and higher standards of living for all. It recognises the need for more firms to innovate and for more engagement in networks 'to take advantage of technological advances and R&D that is undertaken elsewhere'[119]; and
- The innovation strategies of Northern Ireland and Scotland also acknowledge the importance of knowledge exchange between firms and other actors in the innovation ecosystem[120].

In addition, the project partners note that the OECD has identified the need for interventions in border regions to ensure that cross-border innovation opportunities are available to SMEs – reflecting the reality that innovation and the transfer of knowledge do not stop at borders[121].

In summary, the Evaluation Team is of the view that the Co-Innovate project offers the potential to contribute to a range of strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term.

10.11 **Barriers to Cross-Border Cooperation**

The Project Partners note that the only barrier to cross-border cooperation that the priority axis is not addressing relate to the nature of costs which cannot be supported through the Programme, particularly under Strand 4. Specific costs cited which cannot be funded include equipment, materials, subcontractor costs, training consultancy costs. The Project Partnership notes that these costs are eligible for support under similar R&I interventions.

10.12 **Exit Strategy**

Co-Innovate programme activity is anticipated to complete in 2021. At that juncture, the project partners envisage that there will be a legacy of improved SME innovation capability, cross-border relationships, experience of cross-border working and consequent appetite for cross-border R&I collaboration that development agencies can exploit and build upon.

According to the project partners, the long-term benefits/durability of the outputs of the proposed project will include:

[119] Enterprise 2025. Department of Jobs, Enterprise and Innovation (Ireland), 2015.
[120] Department of Enterprise, Trade and Investment, Northern Ireland Innovation Strategy, 2014-2025, 2014; and Scottish Enterprise, Innovation Strategy 2015-2018, 2015.
[121] OECD, Regions and Innovation: Collaborating across Borders, 2013.

- 1,408 SMEs will have considerably heightened awareness of the value and potential for R&I in their business. Many will be motivated to continue developing R&I activity and capability in their business;
- 469 SMEs will have participated in detailed Innovation Audits that will provide a framework for them to implement their visions beyond the life of this project;
- Support agencies engaged in Strands 1 and 2 will have knowledge and experience that will continue to be of benefit after the programme has ended;
- The Network projects formed will continue in existence (and may grow and flourish further), providing a platform and support structure for R&I activity by SMEs;
- The relationships that at least 85 SME partnerships develop with academic institutions will persist. This will encourage academic institutions to consider further partnerships with SMEs in other programmes.
- The number of enterprises exporting will increase, with consequent improvement in growth and employment performance across the eligible region.

11. CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

11.1.1 Overview of activity supported

Seven projects have been funded under Specific Objective 1.1 of the R&I Priority Axis with the commitment of c. €57.6m of funding to increase business and industry-relevant research and innovation capacity across the eligible region within the Health and Life Sciences and Renewable Energy sector. Notwithstanding a number of issues faced by each of the projects, each are progressing with their PhD (or above) led research and the majority of the projects have identified the businesses that will benefit from direct financial support to take forward additional R&I activity.

One project - the Co-Innovate Programme – has been funded under Specific Objective 1.2 with the commitment of c. €22.4m of funding with the aim of increasing the number and capacity of SMEs engaged in cross-border research and innovation activity in the region aimed at the development of new products, processes and tradable services. To date, project delivery has exclusively focused around the delivery of the knowledge transfer and capability strands of the Programme (Strands 1, 2 and 3) with the initial approval of businesses/projects to receive financial support (through Strands 4 and 5) only recently commenced.

11.1.2 Key areas of best practice and learning

Encouragingly, the projects partners in receipt of support under Specific Objective 1.1, cited a number of key areas of best practice and learning which have, in their view:

- Supported project delivery;
- Enhanced levels of cross-border and transnational knowledge transfer and collaboration;
- Created a joint sense of project ownership and removed perceptions of the project being location-centric;
- Created a greater 'Centre' ethos (as opposed to the project being a broker of individual research projects); and
- Supported the potential for longer-term sustainability after INTERREG VA funded period.

Specific examples of the good practice cited by the Projects Partners include:

- Development of research staff's knowledge, skills and commercial acumen through the delivery of academic and industry secondments in other areas is the eligible region (Bryden Centre, BREATH);
- Delivery of Research Colloquia at which PhD students have participated in a two-day away-day during which they were required to present the progress of their respective research projects engage in team-building activities and problem-solving group projects (Renewable Engine);
- Geographical rotation of the project's communication and outreach activities (e.g. ECME, NWCAM, Renewable Engine);
- The utilisation of industry facilities (e.g. NIACE) to support project delivery (NWCAM);
- Research staff being allocated a supervisor in another area within the eligible region to support project progress and their development (Bryden Centre);
- Utilisation of the research base generated through the project partners to leverage additional funding which has, in turn, encouraged additional stakeholders to join the project (SPIRE 2);
- The utilisation of dedicated 'Innovation Brokers' to support the commercialisation process (NWCAM);
- The establishment of a project management and team communication platform (using the 'Basecamp' software), which provides an opportunity for research staff to contribute to research projects and papers (which they are not primarily responsible for) from their inception (renewable Engine) (Renewable Engine);
- Joint training sessions focusing on developing transferable and 'real-world' skills such a resilience, entrepreneurship, presentation and time management skills (ECME);

- The delivery of scientific meetings which bring together the academic institutions to facilitate knowledge transfer and good practice (all projects); and
- The establishment of an informal 'Project Managers' Group has facilitated open discussion in relation to INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allows for cross-over of learning and insights that have been gained by each project manager (all projects).

Ultimately, it is the view of the Project Partners that the collaborative working has served to draw together different but complimentary research strengths and in doing so, strengthened the capacity and capability of the academic institutions to undertake collaborative R&I for the ultimate benefit of business and industry.

In relation to the Co-Innovate Programme (supported under Specific Objective 1.2), the project partners note that whilst the Programme's structure and content is potentially too elongated (particularly at Strand 2), the multi -faceted 'umbrella' of support delivered through the Co-Innovate Programme is unique and offers the potential to take SMEs on a journey which will increase their knowledge and understanding of innovation, enhance their capability to engage in a collaborative project and ultimately de-risk their initial steps into undertaking a cross-border/transnational collaborative by contributing towards its financial costs. Linked to this, it was noted that the 'funnel' approach and content of support has served to 'handhold' businesses through an unfamiliar environment and safeguard monies by ensuring that business are questioned and challenged at each strand of support.

11.1.3 *Synergies between projects*

Our discussions with the Projects Partners indicate that a number of synergies have emerged (both realised to date or currently being explored) between the individual projects funded under Specific Objective 1.1, most notably between the Renewable Engine, Bryden Centre and SPIRE 2 projects which focus of the area of renewable energy. Example of synergies include:

- A number of PhD students from the Renewable Engine project attended the Bryden Centre Summer School at UHI during 2019 which the Project Partners indicate served to (inter alia) enhance levels of cross-project industry engagement, garner a greater understanding of each project's research focus and capabilities;
- The Bryden Centre, Renewable Engine and SPIRE 2 are working closely together with the Advanced Forming Research Centre (AFRC) at University of Strathclyde, Energy Technology Partnership (Scotland) and CASE (NI) in delivering regular joint showcasing and presentations of the PhD work in renewables and energy storage at events such as All-Energy Conference and Exhibition in Glasgow. The event in 2019 was deemed by the Project Partners to have been a major success with several Bryden Centre presentations being made in collaboration with both Renewable Engine and SPIRE 2. Preparations are underway for the Innovation Zone showcase at All-Energy in 2020;
- SPIRE 2's management team at Ulster works closely with the co-located ECME and Centre for Personalised Medicine staff across common Doctoral College activities including generic training and development of PhDs and in delivering on the Marie Curie principles for research;
- Given their respective research strengths, the Renewable Engine and Bryden Centre is actively exploring the potential to collaborate in relation to a project focused around the area of anaerobic digestion; and
- Discussions are ongoing between the Bryden Centre and SPIRE 2 project to identify opportunities for joint PhD training.

A number of project partners also suggested that support delivered through their respective project's may also serve to stimulate businesses engagement in wider collaborative R&I supports that exist at different stages on the Innovation Escalator (e.g. Innovation Vouchers, the Knowledge Transfer Programme).

Whilst the Co-Innovate Project Partners (supported under Specific Objective 1.2) note that they have attended a number of SEUPB-facilitated events/information days with the management teams of the other INTERREG VA Priority 1 projects, to date they suggest that there have not been any overt synergies between the projects largely due to the fact that the seven projects funded under Specific Objective 1 are supporting activities focusing on earlier Technology Readiness levels (i.e. on undertaking research in the R&D&I continuum) whereas the Co-Innovate Programme is more overtly focused on supporting projects which are at higher TRLs and closer to the market (i.e. on undertaking innovation in the R&D&I continuum).

Notwithstanding this, the Project Partners suggest that the support delivered to date (i.e. under Strands 1 to 3) has served to increase businesses' preparedness to engage in other collaborative R&I supports, both within and across jurisdictions, on the innovation escalator. Indeed, as noted, businesses that did not proceed onto further strands of support have been signposted to other R&I supports which are deemed to be more relevant for their stage of development.

11.1.4 Reasonableness of Targets and Indicators established for the Priority Axis

Based on its review of the output and result indicators/targets established for the Investment Priority, the Evaluation Team makes the following observations in relation to their reasonableness:

- Whilst noting that that the Common Output and Results Indicators have been set by the Commission and agreed by Member States to support EU-wide measurement and comparison, when viewed in the context of the Evaluation logic chain - which illustrates the intrinsic linkages between an intervention's aims, inputs, activities, outputs and outcomes – the output indicators appear to more overly representative of the 'activities' and 'inputs' being delivered under the Priority Axis, whilst the Results Indicator identified under Specific Objective 1.1 is more overtly representative of an 'Output'.

  Whilst the Northern Ireland Guide to Expenditure Appraisal and Evaluation (NIGEAE) and Green Book guidance reflects the importance of establishing activity-based targets, these should be viewed as a 'means-to-an-end'. That is to say, their delivery should be seen as an important step in facilitating the ultimate achievement of an intervention's stated outputs, outcomes and ultimate aims (in this case the overarching Specific Objectives). In this regard, caution should be taken in utilising the stated output targets that have been established for the Investment Priority as an indicator that the Priority Axis has ultimately delivered value-for-money.

- On review of the number and nature of Common Output indicators, we are of the view that the Commission should have adopted fewer (or different) specific targets/indicators as (for those established) the delivery of a single element of activity offers the potential to contribute to the achievement of multiple indicators and, in doing so, may potentially create a 'false' sense of achievement in the context of what has actually been delivered under the Investment Priority.

- The overall Results Indicator for Specific Objective 1.1 is to increase the annual number of peer-reviewed journal and conference publications in two target sectors (Health and Life Sciences and Renewable Energy) with cross-border authorship and with the potential to create economic impact from 4 to 75 by 2023. In relation to this we note the following:

  - Based on the INTERREG VA Operational Programme, the Evaluation Team understands that the Managing Authority carried out a survey-interview of higher education institutions in the region to establish the number of peer-reviewed journals and conference publications to establish the annual baseline (which was subsequently identified as 4). However, based on the outputs from their own research activity, a number of Project Promoters questioned the source of the identified baseline, suggesting the number appeared low, and by association then, potentially served to overinflate the potential impact that would be made by the Investment Priority.
  - Given the fact that the annual number of peer-reviewed journal and conference publications would likely ramp-up in line with the levels of research activity being undertaken, in retrospect it would have been beneficial for annual quantified targets to have been established to ensure that progress could be measured towards the annual 2023 target at different annual points (as opposed to in 2023).
  - Based on our discussion with Project Promoters, our review of SEUPB's LoOs and Project Assessment materials and completed monitoring materials, ambiguity exists as to the specific

nature of the Result Indicator. Whilst noting that the Results indicator indicates that the quantified target relates to the annual number of peer-reviewed journal and conference publication, our review of SEUPB Stage 1 and 2 Assessment reports for individual projects appears to indicate that this target is being interpreted in terms of cumulative rather annual outputs.

– It is unclear as to how a publications potential to 'create economic impact' could be measured in practice or its usefulness as the overall indicator to show progress towards the overarching Specific Objective 1.1 which is overtly focused on increasing business and industry-relevant research and innovation capacity.

- NIGEAE and Green Book guidance indicates that 'Efficiency'- the degree to which an intervention has achieved the maximum output from a given set of inputs - is a key measure of determining the value-for-money that has been provided by an intervention. On consideration of the scale of investment made at an individual project level and the Output and Results Indicators that have been established, the Evaluation Team would have reservations as to whether SEUPB has the potential to fully deliver on this indictor of value-for-money. For example, if the Results indicator is reflective of the total number of peer-reviewed journal and conference publications (as opposed to the annual number), the fact that the Bryden Centre project is potentially contributing 91% of the overall target suggests that the scale of the target is, in retrospect too low, and SEUPB could potentially have derived additional outputs by identifying a relatively higher target.

  Similarly, the number of enterprises (N=20) anticipated to be supported through Specific Objective 1, appears low given the quantum of funding being provided and when viewed in the context of other similarly focused interventions available within the eligible region (e.g. Invest NI's Competence Centre Programme, Grant for R&D Programme etc.) and the overall focus of the Specific Objective.

- The Evaluation Team is of the view that greater focus should have been placed on ensuring that the Results indicator associated with Specific Objective 1.2 adhered to the 'SMART' (Specific, Measurable, Achievable, Realistic and Timebound) principles. Whilst the Evaluation Team is not privy to the target setting methodology or sources of information that was adopted/utilised by SEUPB to quantify the Results indicator target, if read literally, the scale of the target appears unachievable in the context of the support that is anticipated to be delivered through the Co-Innovate Programme. In addition, it is unclear as to why the target has been limited to the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations on the basis that the project is ultimately seeking to support SMEs within the entirety of eligible region (including SW Scotland and the Highlands and Islands) and project delivery is being taken forward on this basis (as well as being included by the Project Promoter against the Results indicator target). As such, greater attention should have been given to ensuring this indicator was more 'achievable' and 'realistic'.

  In summary, based on our review of the targets established, the significant scale of investment made through the Priority and the progress that has been made by the individual projects at this interim stage, the Evaluation Team is of the view that SEUPB could potentially have secured greater levels of VFM in the event that more challenging SMART targets had been established at the outset.

11.1.5 *Extent to which the Priority Axis Output & Result Indicators have been achieved*

Notwithstanding the concerns expressed in relation to the reasonableness of the targets established, the Evaluation Team has undertaken an interim assessment of the progress made towards Output Indicators and, in the context of Specific Objective 1.1, the Result Indicator.

Specific Objective 1.1

As detailed in Table 11.1, whilst support is continuing to be delivered to business and industry, many of the output indicators have already been achieved and in most cases, exceeded by some considerable margin. Unsurprisingly, given the fact that the research elements of the projects continue to be undertaken, coupled with the reported delays in the recruitment of research staff, the number of PhD (or above) level research is currently 58% below target.

Subject to a small number of the projects receiving an extension to the timeframes stipulated within their letter of offer (NWCAM and Bryden Centre), the Evaluation Team is not aware of any specific factors that will inhibit the overall achievement of the stated outputs by the end of the project period.

Table 11.1: Overview of progress made towards the Output Indicators under Specific Objective 1.1

Output Indicator	Programme Target	Combined project targets (based on project applications)	Actual Output								Variance from Programme Target	Variance from Combined project targets
			BREATH	Renewable Engine	NWCAM	ECME	SPIRE2	CPM	Bryden Centre	Total		
No. of enterprises receiving support	20	78	5	10	9	5	12	4	47	**92**	360%	18%
No. of enterprises receiving grants	10	26	0	3	-	-	2	3	-	**8**	-20%	-69%
No. of enterprises receiving non-financial support	20	78	5	10	9	5	12	4	47	**92**	360%	18%
Years of PhD (or above) level research	514	636	39.83	24.42	23.62	33.6	29.81	32.57	33.29	**217.14**	-58%	-66%
No. of enterprises cooperating with research institutions	10	78	8	10	9	0	12	5	47	**91**	810%	17%
No. of enterprises participating in cross-border, transnational or inter-regional research projects	10	75	1	10	9	0	12	4	47	**83**	730%	11%
No. of research institutions participating in cross-border, transnational or inter-regional research projects	5	29	3	4	4	5	4	4	5	**29**	480%	-

In terms of progress towards the Specific Objective's Result Indicator, the Evaluation Team notes that 48 peer-reviewed publications with cross-border authorship have been created, 36% lower than the target (assuming that this target relates to the cumulative rather than the annual number). Whilst noting the concerns raised by the SPIRE 2 project in relation to the achievability of its individual Result Indicator, based on the feedback from the Project Partners, the Priority remains on track to achieve the Result indicator at an overarching level.

Table 11.2: Overview of progress made towards the Result Indicator under Specific Objective 1.1										
Output Indicator	**Programme Target**	**Actual Output**								**Variance**
		BREATH	**Renewable Engine**	**NWCAM**	**ECME**	**SPIRE2**	**CPM**	**Bryden Centre**	**Total**	
No. of peer reviewed publications with cross-border authorship	75	21	-	-	4	6	17[122]	0	48	-36%

Specific Objective 1.2

The progress made towards the Output Indicators established under Specific Objective 2 should be viewed in the context that support is continuing to be delivered under the knowledge transfer and capability strands of the Programme (Strands 1, 2 and 3) and the initial approval of businesses/projects to receive financial support has only commenced (hence no progress has been made towards a number of the output indicators). As noted in Section 11.1.6 and elsewhere in this report, the delays in businesses progression along the Co-Innovate support funnel due to Strand 2 ‘bottlenecks’ and the potential impact of ‘Brexit’ may impact on the project’s overall ability of the project to deliver on all of its Output Indicators (at least within the timeframes stipulated within its current LoO).

Table 11.3: Overview of progress made towards the Output Indicators under Specific Objective 1.2			
Output Indicator	**Target**	**Actual**	**Variance**
No. of enterprises receiving support	1,408	1,131	-20%
No. of enterprises receiving grants	30	0	-100%
No. of enterprises receiving non-financial support	1,408	1,131	-20%
No. of enterprises cooperating with research institutions	50	0	-100%
No. of enterprises participating in cross-border, transnational or interregional research projects	30	0	-100%
No. of research institutions participating in cross-border, transnational or interregional research projects	5	0	-100%
No. of enterprises receiving one to one innovation advice	469	255	-46%
No. of enterprises in receipt of an innovation capability development programme	94	0	-100%
No. of enterprises engaging an innovation intern, on a cross-border basis	70	62	-11%

Table 11.4 provides a summary of the progress made towards the Priority’s overarching Output Indicators.

[122] This includes 4 peer-reviewed REF standard journal publications in the H&LS Sciences field with cross border authorship and 13 other high-quality peer-reviewed publications which have cross-border authorship.

Table 11.4: Overarching progress towards the Priority's Output Indicators			
Output Indicator	**Target**	**Actual**	**Variance**
No. of enterprises receiving support	1,428	1,223	-14%
No. of enterprises receiving grants	40	8	-80%
No. of enterprises receiving non-financial support	1,428	1,223	-14%
Years of PhD (or above) level research	514	217	-58%
No. of enterprises cooperating with research institutions	60	91	52%
No. of enterprises participating in cross-border, transnational or interregional research projects	40	83	108%
No. of research institutions participating in cross-border, transnational or interregional research projects	10	29	190%
No. of enterprises receiving one to one innovation advice	469	255	-46%
No. of enterprises in receipt of an innovation capability development programme	94	0	-100%
No. of enterprises engaging an innovation intern, on a cross-border basis	70	62	-11%

11.1.6 Factors that have impacted on project delivery including the achievement of Project Output and Result indicators and the Priority's Specific Objectives

Each of the Project Partners in receipt of support under Specific Objective 1.1 advise that they have encountered issues that have impacted on the delivery of their respective projects to date.

Whilst noting that some of these issues have combined to slow progress towards elements of the output indicators (e.g. number of PhD years delivered), in general, the Project Partners do not anticipate that these will ultimately have an adverse impact on the longer-term achievement of Project Output and Result indicators and the Priority's Specific Objectives (albeit a number of project partners note that the ultimate achievement of these targets will be conditional on them receiving an extension to the timeframes stipulated in their respective Letters of Offer (e.g. NWCAM, Bryden Centre)).

Examples of issues commonly cited by the projects' partners include:

- **Staff mobility issues -** Difficulties have been encountered in non-EU resident PhD students taking up research positions in the eligible region or travelling outside their eligible region country of research residence due to visa restrictions. A number of the Projects Partners expressed concern that such mobility issues could potentially be exacerbated following the UK's departure from the EU (i.e. following 'Brexit');

- **'Background' and 'foreground' IP issues impacting on business recruitment and wider engagement in research projects -** Several of the projects' partners noted during consultation that they have faced difficulties encouraging business engagement on their respective project's due to concerns relating to IP. For some businesses, these concerns related to the potential for other businesses to use their 'background' IP, resulting in a loss of their competitive position in the marketplace. However, in the majority of cases, the concerns around IP principally related to the fact that industry would not own any 'foreground' IP emanating from the research, with this ultimately being owned by the academic institutions;

- **Delays in the recruitment of PhD students and wider research staff -** The majority of the projects' partners indicated that they had encountered delays in the recruitment of PhD students and wider research staff to support the delivery of their respective project's. A commonly shared view amongst the Partners is that this situation may have arisen due to interrelated demand and supply-side factors.

  On the demand side, it was noted that the issues may have arose due to the fact that a number of different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the Priority's two sectors (i.e.

Renewable Energy and Life and Health Sciences). This inadvertently created significant demand within the market for these students at the same time, resulting in a shortage of available students and, by association, delays in recruitment.

On the supply side, it was noted by a number of partners that there has been limited appetite from domestic applicants which has potentially resulted from a number of factors including the scale of the research bursary that was available to potential students and/or increasing salaries in the private sector and student costs/fees which may have served to detract potential students from a potential career in research.

As a result of the combination of these demand and supply side factors, a number of partners indicated that they had to ultimately seek applications from potential international PhD students. However, there were subsequent delays in these students working on the projects due to the necessity to secure visas;

- **EU, SEUPB and University Procurement requirements hindering the progression of research -** According to a number of the project partners, the progression of research has been hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed to conduct research;

- **Changes to the research team profile during the delivery of the research projects (including issues relating to staff retention).** A number of the project partners have indicated that there have been a number of changes to the profile of the project's research team during the initial delivery period which has, on occasions slowed project progress;

- **Changes to industrial partners -** A small number of project partners indicated that industry partners have had to be replaced due to specific business' circumstances (e.g. businesses going into administration, businesses having more pressing priorities); and

- **The claims process adversely impacting on business' engagement -** Linked to the previous point, it was noted by a small number of project partners that the administration and bureaucracy associated with the claims process has resulted in a business leaving the project and other businesses not willing to receive the financial support that is currently available through their respective project's.

The Evaluation notes that there are specific issues relating to two projects - CPM and SPIRE 2 - funded under Specific Objective 1.1, which may impact on their ultimate success and potentially the achievability of their respective output and results indicators.

In the case of CPM, two of the project's partners have indicated that, in relation to Research Cluster 4 ('Unscheduled care in Diabetes'), delays in project progress continue due to lack of a named partner in Letterkenny University Hospital to assist the team members to progress the research. As of July 2019, no patient interviews have been completed on this site and the Lead Partner notes that this may mean that the Project Partners will need to plan the main study without the benefit of preliminary data. Ultimately, the Lead Partner suggests that this may impact on the overall success of the main study. Without a named LUH representative on the RC4 team, time is also being lost trying to negotiate access, research approval and recruitment which might delay completion of the 'in-patient' doctoral study.

In terms of the SPIRE 2 project, the Project Partners have indicated that they are unlikely to deliver on their Results indicator of 78 peer-reviewed cross border publications on the basis that the project has only one cross border academic partner (DkIT) and only one PhD contracted in this partner.

In terms of the Co-Innovate Programme (supported under Specific Objective 1.2), the project partners advise that the project has encountered a number of issues in the delivery of the project to date and uncertainty presently exists as to the potential impact of these issues on the overall achievement of the Project's Output and Result indicators and the Priority's Specific Objective. Specific issues cited by the Project's Partner include:

- **Uncertainty of 'Brexit' on business recruitment -** Consultation with the project partner's indicates that there have been delays in approving Strand 4 and 5 projects due to uncertainties that presently exist amongst the business community in the eligible region in relation to the potential impact of the UK's withdrawal from the EU (i.e. 'Brexit'). As noted previously, businesses participating in Strands 4 and 5 are required to contribute 50% of the total project costs. However, it is understood that a number of businesses have expressed reservations to commit funds and resources which may be required to address emerging needs following Brexit.

- **Delays in businesses progression along the Co-Innovate support funnel due to Strand 2 'bottlenecks'-** During consultation the project partners indicated that the requirement for businesses to complete two separate business assessment tools (i.e. a Business Status Review and Innovation Capability Audit), coupled with businesses' availability to engage in the support and provide the requisite information, had served to delay the progress of businesses through to subsequent strands of the Programme's support. In retrospect, the Project Partners suggested that it would have been beneficial to merge the two assessments into one in order to expedite the process and the bureaucracy placed on businesses;

- **Delivery of Programme activity in the Highland's and Island's area of the eligible region -** The project's partners note that levels of activity in the Highland's and Island's area is below that anticipated at the outset due to two interrelated reasons. Firstly, due to its peripheral location, the time required to engage with businesses located on the Scottish Island's on a face-to-face basis (noted as being up to three days) has taken longer than was anticipated at the outset. Secondly, and related to this point, it was initially anticipated that all strands of Programme activity would be delivered in the Highland's and Island's area by two Programme manager (as opposed to availing of external expertise to support programme delivery, as was being utilised in the other areas of the eligible region). However, in retrospect, the Project Partners suggest that the level of resource that was initially allocated was significantly below the level required to deliver the Programme within the stipulated timeframes. As such, it is understood that the Project Partners sought approval from SEUPB (and was subsequently granted approval) for the Programme to utilise external consultants to support the delivery of Strand 2 activity within the Highland's and Island's area; and

- **Cross-border/transnational focus of support limiting engagement from some businesses -** Whilst noting the merits of the cross-border and transnational nature of the support, the project partners are of the view that the need for businesses to engage with academia (as part of Strands 4 and 5) on a cross-border/transnational basis creates geographical/logistical difficulties (perceived or actual) for some businesses, resulting in them unwilling to engage with the Programme, especially when other support mechanisms are available in their home jurisdiction which does not require them to take forward collaboration outside this jurisdiction.

11.1.7 Impact on business and industry

It is the view of the Evaluation Team that the impact of the projects, funded under Specific Objective 1, on business and industry can only be assessed in the longer term given the interim nature of the implementation of projects and the widely recognised time lag between engaging in R&I activities and the realisation of tangible benefits by business and industry. More specifically, time will be required to move the research up the TRL scale and bring the technologies to market (assuming the R&D can be commercialised by the businesses and wider industry). The scale of this time lag will invariably depend on a range of factors including the sector in which the technology is being developed in, the technology's starting point on the TRL scale and associated degree of novelty.

Notwithstanding this, a number of the projects partners noted a number of ongoing positive activities and outputs, which offer the potential to support the longer-term growth and competitiveness of the project's industry members including the development of industrial competencies, IP (NWCAM), development of new and/or adapted products and processes.

Furthermore, anecdotal feedback from a number of the projects partners indicates that their respective project's have served to (at least in part) support the achievement of a range of other more intangible, interim 'measures of success' including:

- Businesses identifying wider research and business development opportunities.
- Businesses increasing their knowledge and understanding of the benefits of working collaboratively with academic institutions which may result in the development of longer-term working relationships;
- Businesses developing a greater understanding of the respective research strengths and capabilities that exists within the academic institutions;
- Academia increasing its understanding of the needs of industry;
- Businesses being supported to take forward commercially focused R&D which may not have been undertaken due to their capacity and capability; and
- The establishment of an industrial focal point for collaborative R&D within the renewable energy and life and health science sectors;

The independent assessment of these tangible and intangible business benefits/impacts will be a core focus of the Evaluation Team's next tranche of research.

In terms of the Co-Innovate Programme, the Evaluation Team undertook an online survey and telephone consultations with 267 businesses that received support through one or more of the first three strands of support delivered by the Co-Innovate Programme (i.e. Strand 1: Innovation Workshop, Strand 2: Capability Review/Business Assessments and Strand 3: Innovation Capability Development (Mentoring) support).

The analysis of businesses' feedback indicates that the majority of businesses (more than 80%) are satisfied with the support that they received and, importantly, have realised the knowledge and capability developments that were envisaged under each strand of support. Of note, the majority of businesses indicated that they have enhanced their knowledge and understanding of:

- The key concepts, practices and principles of innovation, as well as the potential benefits that can be derived from engaging in collaborative innovation;
- How their business is performing relative to other innovative SMEs; and
- The issues that are inhibiting their growth and associated opportunities/actions for development and are taking measures forward to address these issues.

Furthermore, the majority of businesses indicated that they have increased their readiness to ultimately take forward a collaborative R&D project.

Notwithstanding the largely positive feedback received, the Evaluation Team does however note that there was a sizeable minority of businesses that indicated that they were not satisfied with the support that they had received, with frequently raised concerns by this cohort including that they felt the support was too high level and generic, not tailored to the specific needs of the business, there were delays in receiving the outputs from the support and, linked to this, communication around receipt of information and their progress on the programme more generally could have been more effective. Consequently, these businesses indicated that they had not derived aspects of the benefits that were anticipated to be achieved from their participation in the Programme. It appears that these issues are most pronounced in relation to Stage 2 of the Co-Innovate Programme.

Whilst noting that levels of activity are, at this juncture, largely completed for the initial Strands of the Co-Innovate Programme, the Project Promoter should be mindful of the feedback received and seek to address (as far as possible) the issues that have been identified by recipients of support.

11.1.8 Contribution of the Priority Axis to Policy Objectives

The Evaluation Team is of the view that the 8 projects funded under the Priority Axis offer the potential to contribute to a range of economic, energy and life and health science strategic imperatives that exist across the eligible region. However, the actual contribution of the project to these strategic imperatives/targets can only be measured in the longer term (e.g. when the outputs from the research are ultimately implemented).

11.1.9 Appropriateness of the sectors supported by the Investment Priority

It is the view of the Project Partners, and shared by the Evaluation Team, that the sectors supported by the Research and Innovation Investment Priority (i.e. Life and Health Sciences, Renewable Energy and, in the case of the Specific Objective 1.2, Agri-Food/Tech) continue to be appropriate.

Linked to the key tenets of the SMART Research and Innovation Strategy for Smart Specialisation (RIS3), the sectors selected represent the research and innovation priorities where the eligible region has competitive strengths (both within its current research and industry base) to drive economic growth and prosperity, as well as address major societal challenges.

11.2 Recommendations

1. By way of aiding post-project evaluation and potentially supporting the achievement of relatively greater levels of VFM, SEUPB should ensure that all objectives, outputs and result indicators (including established baselines) established for all future programmes adhere to the 'SMART' criteria and are reasonable in the context of the quantum of support being allocated.

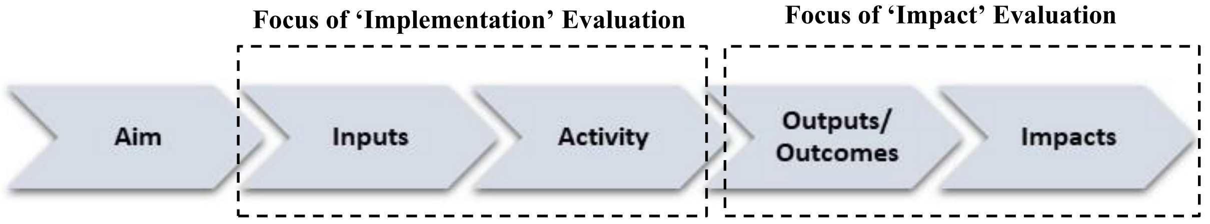
2. Linked to recommendation 1, SEUPB should ensure that robust challenge is given the assessment of individual project's potential contribution to overarching targets indicators.

3. By way of aiding ongoing Evaluation, the Project Partners should be encouraged to review their approach to monitoring and progress reporting with a more overt focus being placed on documenting:

   - The nature and intensity of interaction with business and industry;
   - The impact and relevance of the project's activities for business and industry (i.e. the 'so what?'); and
   - How activities are 'additional' and add-value to those already being carried out by the academic institution

4. The 'logic chain' to Evaluation illustrates the intrinsic linkages between an intervention's aims, inputs, activities, outputs and outcomes (as depicted in Figure 11.1). However, the Evaluation Team understands that SEUPB has commissioned two separate evaluations – an 'Implementation' Evaluation and 'Impact' Evaluation - which focus on assessing the progress made by the Priority (and projects supported therein) at different stages of the logic chain.

Figure 11.1: The logic chain to Evaluation



However, given the interlinkages that exist between each stage of the logic chain, the Evaluation Team is of the view that a more rounded, holistic approach should be taken to Evaluation which would require the assessment of the implementation and impact made by the Priority axis as part of one evaluation. For example, in a scenario in which an intervention does not achieve its anticipated outputs/outcomes or impacts, this would naturally lead to the question as to why such a scenario arose. Based on the logic chain to Evaluation, such a scenario could have arisen as a result of the implementation of the activities of the intervention which, in turn, may have been influenced by the scale and quality of inputs utilised to deliver the activities. Therefore, any rationalisation as to why an intervention's outturns are achieved (or otherwise) requires a 'joined-up' approach to Evaluation focused on each stage of the logic chain.

5. Whilst noting that the delivery of Strand 2 of Co-Innovate activity is largely complete, future project applicants/promoters should be encouraged to ensure that every opportunity is taken to streamline programme delivery in order to maximise participant engagement whilst minimising levels of administration and bureaucracy.

6. The Co-Innovate Lead Partner should be encouraged to undertake a review of its processes for communicating with, and delivering all project related outputs to, recipients of support, ensuring that (as far as possible) both are delivered in a timely manner.

7. SEUPB should request the CPM Lead Project Partner to provide details of the actions that are being taken to resolve the ongoing resourcing issue relating to the lack of a named partner in Letterkenny University Hospital, as well as provide clarity as to how any continuing absence will impact upon the overall delivery of the project (as originally proposed). If the issue cannot be resolved to SEUPB's satisfaction and the issue is likely to materially impact on the delivery of the project, consideration should be given to scale of investment made to the project.

8. Clarity should be provided to all project partners as to how SEUPB is defining the 'cross-border' aspect of the Result Indicator of Objective 1.1.

9. In-light of Recommendation 8, the SPIRE 2 Lead Project Partner should provide clarity as to the project's ongoing ability to deliver on its Result Indicator (of delivering 78 peer-reviewed cross border publications). In the event that the project does not offer the ability to deliver the Result Indictor to the initial level anticipated, careful consideration should be given to any amended target in light of the scale of investment made through the project.

Appendix I - Definitions of sectors and types of R&D activities supported under Priority Axis 1

Definitions of Sectors under Objective 1.1[123]	
Health Sciences	Group of disciplines of applied science dealing with human and animal health. There are two parts to Health Sciences: the study and research knowledge of health and the application of that knowledge to improve health, prevent and cure diseases, and understand how humans and animals' function.
Life Sciences	Any one of the branches of science concerned with the structure and behaviour of living organisms, such as biology, botany, zoology, physiology, or biochemistry. In this context, it further encompasses the fields of biotechnology, biomedical technologies, life systems technologies, pharmaceutical, nutraceuticals, food processing, environmental and biomedical devices.
Renewable Energies	Energy derived from natural processes (e.g. sunlight and wind) that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services.

Definitions of R&D Activities under Objective 1.1	
Basic Research *(excluded)*	Experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
Industrial Research	Planned research or critical investigation aimed at the acquisition of new knowledge and skills for developing new products, processes or services or for bringing about a significant improvement in existing products, processes or services. It comprises the creation of components parts of complex systems and may include the construction of prototypes in a laboratory environment or in an environment with simulated interfaces to existing systems as well as of pilot lines, when necessary for the industrial research and notably for generic technology validation.
Experimental Development	Acquiring, combining, shaping and using existing scientific, technological, business and other relevant knowledge and skills with the aim of developing new or improved products, processes or services. This may also include, for example, activities aiming at the conceptual definition, planning and documentation of new products, processes or services. Experimental development may comprise prototyping, demonstrating, piloting, testing and validation of new or improved products, processes or services in environments representative of real-life operating conditions where the primary objective is to make further technical improvements on products, processes or services that are not substantially set. This may include the development of a commercially usable prototype or pilot which is necessarily the final commercial product, and which is too expensive to produce for it to be used only for demonstration and validation purposes. Experimental development does not include routine or periodic changes made to existing products, production lines, manufacturing processes, services and other operations in progress, even if those changes may represent improvements.

Notes:

- Typically, **industrial research** activities will focus on progressing a new technology/product through Technology Readiness Levels[124] (TRL) 2 and 3.
- Typically, **experimental development** activities will focus on supporting both Development (TRLs 4 and 5) and Innovation activities (TRL 6-8) to a point when the new technology/product can enter into production.

[123] Source: Output Indicator Guidance document for Objective 1.1 (January 2017).

[124] Technology readiness levels (TRL) are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. They are determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities. TRL are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology.

Appendix II – Overview of Key Strategies

EU2020 Objectives

Europe 2020 – A Strategy for smart, sustainable and inclusive growth – is the EU's response to the Great Recession, which was the period of general economic decline observed in world markets during the late 2000s and early 2010s. The Strategy aimed to ensure that Europe emerged stronger from the economic and financial crisis.

Europe 2020 put forward three mutually reinforcing priorities:

- **Smart growth**: developing an economy based on knowledge and innovation.
- **Sustainable growth**: promoting a more resource efficient, greener and more competitive economy.
- **Inclusive growth**: fostering a high-employment economy delivering social and territorial cohesion.

Of particular relevance to Priority Axis 1: Research & Innovation, smart growth means strengthening knowledge and innovation as drivers of future growth. This requires improving the quality of education, strengthening research performance, promoting innovation and knowledge transfer through the Union, making full use of information and communication technologies and ensuring that innovative ideas can be turned into new products and services that create growth, quality jobs and help address European and global societal challenges But, to succeed this must be combined with **entrepreneurship, finance and a focus on user needs and market opportunities.**

The Strategy contained five measurable EU targets for 2020 that were anticipated to steer the process and be translated into national targets: for employment; for research and innovation; for climate change and energy; for education; and for combating poverty. They represented the direction that it was considered Europe should take.

- 75% of the population aged 20-64 should be employed.
- 3% of the EU's GDP should be invested in R&D.
- The "20/20/20" climate/energy targets should be met (including an increase to 30% of emissions reduction if the conditions are right).
- The share of early school leavers should be under 10% and at least 40% of the younger generation should have a tertiary degree.
- 20 million less people should be at risk of poverty.

The Atlantic Strategy

The 'Atlantic Strategy' is the EU's Maritime Strategy for the Atlantic Ocean area. It provides for a coherent and balanced approach that is consistent with the EU 2020 agenda. It is largely focused on helping communities living and working on the Atlantic coast deal with new economic realities, but also recognises that the EU shares responsibility for stewardship of the world's oceans. Broadly speaking the strategy cover the coasts, territorial and jurisdictional waters of the five EU Member States with an Atlantic coastline – France, Ireland, Portugal, Spain and the United Kingdom.

The Strategy is based around five themes. Actions within each will contribute to the overriding objective of creating sustainable jobs and growth.

Theme	Proposed Actions
Implementing the ecosystem approach	Management of human activities in the Atlantic must deliver a healthy and productive ecosystem. The ecosystem approach is the basis for marine management in both the Common Fisheries Policy and the Marine Strategy Framework Directive. However, the implementation processes for ensuring sustainable fisheries and achieving a good environmental status are still largely separate in practice and will require additional effort in the Atlantic Ocean area. Therefore, the strategy for the Atlantic must focus on developing the following aspects: • Fisheries have been a central plank in economies on both sides of the Atlantic. However, single-species management must make way for multi-species long-term plans that take into account the wider ecosystem. • Aquaculture, which can satisfy EU demand for healthy and sustainably produced fish products over and above the level that can be provided by capture fisheries. The strategy, therefore, promotes spatial planning as a tool for implementing the ecosystem approach in the Atlantic Ocean area. Such a process should strengthen coherence, connectivity and resilience of marine protected areas in the Atlantic in line with the EU biodiversity action plan. • Finally, Atlantic oceanic circulation drives changes in European terrestrial as well as marine ecosystems. Forecasting future changes in Europe's climate and adapting to these changes will never be achieved without a better understanding of the Atlantic. This calls for sustainable observation systems, from space and at sea, of key marine variables.
Reducing Europe's carbon footprint	As climate change mitigation is an integral part of all EU policies, the strategy focuses on the following elements: • The Atlantic has stronger winds than the other seas that wash Europe's shores. Not only does this offer clean energy but it can also contribute to reducing dependency on distant sources of fossil fuel. By 2020, around 20% of the European offshore wind installed capacity could be located in the Atlantic basin. • The potential of the Atlantic's powerful waves and strong tides needs to be exploited as well. The predictable nature of energy from tides can complement the fluctuating energy from wind. However successful deployment of large scale offshore renewable energy will only happen if grid connections are ensured to link the main production centres to the consumption. • Changes in maritime transport will also contribute to the carbon footprint reduction in the Atlantic.
Sustainable exploitation of the Atlantic seafloor's natural resources	This strategy aims to focus on the following aspects in order to develop the sustainable exploitation of the Atlantic seafloor's natural resources: • Tackling the challenges in commodity markets and on raw materials by emphasising the need to increase investment in Europe's natural assets whilst ensuring that minerals are extracted under safe conditions that respect the environment and workforce. • Marine research institutes on both sides of the Atlantic are well placed to deepen understanding of what the rich biodiversity of the ocean can offer further for food, fuel and pharmaceuticals whilst preserving its ecosystem functions. • Access to the data produced by research institutes and other public authorities has not always been easy in the past. The EU's marine knowledge 2020 initiative will support business and conservation authorities by providing a unique access point for marine data harmonised over sea-basins, so reducing the cost of assembling the data necessary to design, build and operate coastal or offshore infrastructure. Unlocking the patrimony of marine data will not only make existing business processes more competitive but will

Theme	Proposed Actions
	stimulate innovation by opening access to previously excluded researchers and small businesses.
Responding to threats and emergencies	The EU needs to be prepared for threats and emergencies in the Atlantic whether they are caused by accidents, natural disasters or criminal activity. The following aspects are priorities for the Atlantic Ocean area: • The adoption of important legislative measures on maritime safety; • In addition, early warnings require continuous monitoring of the sea, fast transmission of information, coordination of response teams and mobilisation of expert advice. • The Atlantic is Europe's lifeline for trade. Europe's security of supply must be absolutely secure and the trafficking of arms, people and drugs must stop.
Socially inclusive growth	Whilst there is considerable variation along the Atlantic coast, many communities need to cope with a decline in employment in fisheries and shipbuilding, the shift of mass tourism to sunnier climes and the tendency of elderly people to choose the coast for retirement. The challenge is to ensure that new high-added-value jobs are created at the coast and at the same that those who seek employment in the new economy have the right skills to do them. • Wider mutual recognition of training, including the next generation of marine scientists, re-training and professional qualifications are required to retain maritime expertise and restore the attractiveness of maritime professions. • Regional clustering of maritime industries with educational establishments can ensure a skilled workforce and promote labour mobility within sectors. The advent of new communication technologies means that a critical mass of industries and researchers in geographically separate locations can set up virtual clusters. The strategy has a focus on encouraging the development of these clusters through territorial cooperation projects. • A discerning tourism can help regenerate some Atlantic coastal areas but it needs to attract all-year-round trade rather than summertime only in order to support quality jobs. The Atlantic's rough natural beauty, rich biodiversity, traditional seafood cuisine and Celtic culture are assets that can be readily exploited. Nautical activities are an important source of revenue and a creator of high-value jobs, however, the Atlantic coast has a major deficit in berths especially for large recreational vessels. The Atlantic strategy incorporates the opportunities for development in this field.

Following the development of the Atlantic Strategy document, an Action Plan was developed, with the intention that it should be implemented through to 2020. These action areas are designed to meet the challenges of the Atlantic strategy and deliver smart, sustainable and socially inclusive growth and jobs. It comprises an indicative set of action areas for research and investment to tackle common challenges. Addressing these priorities can promote innovation, contribute to the protection and improvement of the Atlantic's marine and coastal environment, improve connectivity and create synergies for a socially inclusive and sustainable model of regional development.

Priority	Specific Objectives (NB If you think that your project hits on any of these, look closer at the Action Plan as the objectives are further split out)
1: Promote entrepreneurship and innovation	• Sharing knowledge between higher education organisations, companies and research centres; • Enhancement of competitiveness and innovation capacities in the maritime economy of the Atlantic area; • Fostering adaptation and diversification of economic activities by promoting the potential of the Atlantic area.
2: Protect, secure and develop the potential of the Atlantic marine and coastal environment	• Improving maritime safety and security • Exploring and protecting marine waters and coastal zones • Sustainable management of marine resources • Exploitation of the renewable energy potential of the Atlantic area's marine and coastal environment
3: Improve accessibility and connectivity	• Promoting cooperation between ports.
4: Create a socially inclusive and sustainable model of regional development	• Fostering better knowledge of social challenges in the Atlantic area; • Preserving and promoting the Atlantic's cultural heritage.

The Horizontal Principals

The three Horizontal Principals of xxx are as follows:

Sustainable development	This principle seeks to ensure that the Programme supports activity that promotes sustainable development and creates sustainable communities by safeguarding and requiring the sustainable use of, existing resources to enhance the long-term management of, and investment in, human, social and environmental resources for future generations.
Equal opportunities and non-discrimination	In accordance with Section 75 of the Northern Ireland Act 1998, the Employment Equality Act (1998) and the Equal Status Act (2000), as amended by the Equality Act (2004) in Ireland and the Equality Act (2006) in Scotland, operations part-financed by the Programme shall comply with and, where appropriate, contribute to Community policy and legislation on equal opportunities and non-discrimination. Accordingly, the Programme will have due regard for the need to promote equality of opportunity: • Between persons of different religious belief, political opinion, racial group, age, marital status or sexual orientation: • Between men and women generally; • Between persons with a disability and persons without; • Between persons with dependants and persons without; and • Without prejudice to the above, have regard to the desirability of promoting good relations between persons of different religious belief, political opinion or racial group.
Equality between men and women	The Programme shall pursue the objective of equality between men and women and take appropriate steps to prevent any discrimination during the preparation, implementation, and monitoring and evaluation stages of the programme. Gender equality aims to ensure that men and women enjoy the same rights and opportunities; with equal value and weighting attributed to the different behaviour, aspirations and needs of women and men

Appendix III – Bryden Centre Project Summaries

Lead Institute	Start Date	PhD Title	Project Summary:
UU	01/10/2018	**Performance Study and Validation of the Downdraft Biomass Gasification Process for CHP Plants**	The aim of this project is to develop a comprehensive performance analysis of an economical concept for biomass supply chain management, pre-treatment, production of syngas and utilisation of biomass/waste, by means of biomass gasification for electricity and heat production. Main activities of the project will be: 1. *Process modelling* - develop the feedstock supply chain and gasification process models for the integrated biomass gasification and CHP system. The models developed will be used to evaluate the technical, economic and environmental performance of micro-generation fuelled by biomass in the building sector; 2. *Experimental study and model validation* - experimental work and analysis of selected feedstocks for a range of process conditions, leading to pilot test results. 3. *Process integration* - syngas produced by a downdraft gasifier will be cleaned up, analysed and fed to an internal combustion engine for the application of combined heat and power. 4. *Assessment* - techno-economic and environmental assessment of the full bioenergy production chain
UHI	01/05/2018	**Develop a multi-disciplinary optimisation method for application to the automotive, Energy and Environmental sectors**	Multi-Disciplinary Optimisation (MDO) design process assesses the sensitivity of a system to all of its constituent variables. It is anchored around a system-modelling method and uses various numerical-simulation tools to predict how changes to the variables affect the system. It thus explores the entire design space (without prejudice, and using a Design of Experiments approach to ensure efficiency) to arrive at a set of variable settings that best meet the performance requirements while also satisfying the prevailing constraints. The use of MDO methods is now prevalent in the aerospace and motorsport industries, but they can be applied to any complex, multi-variate system. The intention of this project is to create and apply an MDO method across a variety of sectors: 1. Determine the optimum renewable energy solution for an 'off-grid' community; 2. Asses the optimum combination of constituent technologies for a wave-energy device. 3. Optimise a hybrid CHP energy solution, understanding the costs of over-specification and redundancy, and evaluate the impact of incorrect assumptions. 4. Determine the influence of bio-renewable fuels and fuel additive mixtures on overall vehicle engine efficiency, exhaust conditions and after-treatment requirements
UHI	01/05/2018	**Community-scale tidal power generation – is it feasible in the INTERREG VA area?**	The INTERREG VA area hosts substantial tidal energy potential; Scotland alone accounts for 25% of Europe's resource. Scotland developed and implemented a sectoral marine plan for tidal energy in 2013. However, sites with less than 30MW capacity were excluded from the plan. There is increasing interest in small tidal energy projects to decarbonise energy supply to remote areas. However, there has been no definition of the science required to identify community-scale development locations. The key is the assessment of accessibility and suitability of tidal power resource, and the project would emphasise the application of hydrodynamic models in potentially suitable locations (e.g. sills in sea lochs, tide races around headlands etc.) with associated model development and field validation. The feasibility of exploiting this resource will be determined through a scoping analysis of environmental, technical, social, economic, and legal factors, potentially through case studies including technological and socio-economic opportunities and constraints. Experience of currently operating tidal turbines will define the depth of water necessary for different foundation and turbine technologies, under keel clearance, and cable laying. The outputs will include a method for small-scale tidal energy scoping studies and Regional Locational Guidance documents for coastal communities in the INTERREG VA area.

Lead Institute	Start Date	PhD Title	Project Summary:
UHI	01/10/2018	**Marine Bioenergy; what does third-generation marine biofuels mean for society?**	For marine bioenergy to make a significant contribution to the de-carbonisation of the energy mix, then the scale of production would mean unprecedented development within the marine environment. For any industry to operate effectively within a community and to expand, the industry requires a social licence to operate, going beyond what is just required for strict compliance with the environmental regulation or law (Gunningham et al. 2004). Marine bio-energy development would fall under the regulatory framework developed for aquaculture, and so the development of sites for this new industry would require extensive public consultation through the planning process. As such the ability for any new industry to develop will ultimately be determined by how the industry is thought of in society, and how marine bioenergy industry reflects the values of the society in which it operates (Hamouda et al. 2005). In Scotland and to a certain extent Europe, it is becoming increasingly evident that the existing aquaculture industry is losing its social licence to operate in certain locations (Leith et al. 2014). Can the marine bio-energy industry avoid the mistakes of the existing aquaculture industry and how can it foster a social licence to operates as it develops? This PhD will aim to: 1. Understand how the public perceives marine bio-energy, and how this varies between coastal and non-coastal communities. 2. Understand how the current regulatory framework interacts with a social licence through aspects such as industry transparency, stakeholder consultation and information availability 3. Develop tools that will foster social licence to operate for the emergent industry. This research will involve extensive primary research into public attitudes to marine bioenergy at a range of spatial and social levels. Approaches will include quantitative assessment using publicly available statistics on demographics which can be matched with potential development sites. It will also require quantitative and qualitative exploration using interviews and focus groups to collect data from specific individuals or groups of stakeholders in targeted demographic ranges and locations.
UHI	01/10/2018	**Use of tidal flow areas by seabirds and the potential interactions with tidal stream renewable energy**	Many questions remain unanswered regarding the use of areas of high tidal flow by seabirds and the potential interactions and impacts of marine renewable energy developments. These knowledge gaps can be significant constraints on the licencing of marine renewable developments. The initial part of this project will use existing telemetry data (collected by the RSPB FAME project) to better understand how seabirds broadly utilise tidal flow areas. Following on from this and using existing and newly collected data, the student will examine how key seabird species interact with tidal generation technologies, if/how they utilise the associated structures, and how this influences collision risk/displacement effects. Bluemull Sound in Shetland would be a suitable study site due to the ability to undertake land-based vantage point watches (seabird count and behavioural data), and the presence of a tidal stream energy company (nova-innovation) which has cameras installed on at least one turbine. There may also be the potential to track seabirds (black guillemot, shag) present in the vicinity, and additional apparatus could be deployed at the location (providing data on both birds and their potential fish prey).
UHI	01/10/2018	**Behavioural changes of top predators related to tidal-stream energy extraction – using Unmanned Aerial Vehicles (UAVs) to measure animal distribution**	Top predators such as seabirds target tidal stream sites for foraging opportunities. High flow speeds, upwelling or shear may enhance prey availability and foraging efficiency. Regulators need information on animal distribution to understand interactions with tidal energy developments, to inform licensing and management. Potential impacts include blade-strike, displacement from preferred habitat, habitat-modification, or changes to the predictability and availability of prey. Existing survey techniques use costly (so infrequent) vessel or aeroplane surveys which limit understanding of seasonal trends. Shore-based vantage point surveys suffer from reduced detectability of animals with increasing distance from the observer. The aim of this interdisciplinary PhD is to develop and demonstrate UAVs as a cost-effective technique to investigate how top predators interact with tidal energy sites or technologies, with concurrent imaging of surface hydrodynamic characteristics as a potential classifier of habitat-type for animals targeting these sites. The project will build on proof-of-concept surveys carried out at the MeyGen site (Pentland Firth, Scotland) and will: investigate UAV sensors to detect animals and surface hydrodynamic features; develop algorithms for automated detection and classification; validate UAV measurements against ground-truth measurements; investigate behavioural associations between foraging seabirds and hydrodynamic characteristics, and how these may be changed by tidal stream turbines.

Lead Institute	Start Date	PhD Title	Project Summary:
UHI	01/10/2018	**Enhancement of Marine Energy Assets through Validated Numerical Modelling and Optimisation, and the Adoption of Building Information Modelling (BIM) for Lifecycle Management**	This project will look at the optimisation of both the design and operation of wave and tidal energy devices. This approach will be validated through the acquisition of prototype performance parameters, including measurements of, for example, the loading on tidal turbine blades These validation data will be incorporated into a multi-disciplinary optimisation (MDO) approach which will model the entire device with the target of reducing operating cost and deliver a higher performance of Wave Energy Converters (WEC) and Tidal Turbines. The numerical modelling will include fluid-structure interaction, power take-off, controls, materials, etc. The initial approach will be to adapt and develop the open-source NASA MDAO optimisation tool for application to marine energy. The acquisition of prototype performance and health-monitoring data, plus the numerical modelling at the heart of the MDO process will provide input into a marine-energy equivalent of Building Information Modelling (BIM). The adoption of BIM has demonstrated a key role in delivering efficiency and cost reduction across the supply chain in the construction sector. Application to marine energy projects could be a major enabler in cost/risk reduction through the entire lifecycle of wave and tidal energy projects.
UHI	01/10/2018	**Passive acoustic monitoring and automated detection of gadoid fish species in marine renewable development areas**	Interaction with ecosystem services and other users of the sea are key aspects of environmental impact assessments for marine renewable development. Although "fisheries sensitivity" maps exist, they are coarse resolution and detailed assessment of key activities e.g. spawning at potential development sites can be difficult. Passive Acoustic Monitoring (PAM) for underwater sound produced by some commercial species during spawning (e.g. gadoids) offers the potential for continuous observations over a period of interest. This approach has been shown to provide detailed information on the extent of fish spawning aggregations. Further, PAM can be applied in the post-construction period, whereas it is normally not possible to undertake trawl surveys within the boundaries of renewable development. This project will review sound production by commercial fish species, with a particular focus on gadoids. The project will assess the suitability of passive acoustics for monitoring spawning aggregations and develop species-specific classifiers, based on test data collected at known gadoid spawning grounds. Resulting classifiers will then be applied to new data. This technique would revolutionise the current approach to this aspect of EIAs, and might also benefit the development of species-specific classifiers for other species, such as minke whales.
UHI	01/10/2018	**Ecology and recovery potential of flame shells (L. hians) to disturbance**	In the UK *Limaria hians* is found in the Scottish west coast sea lochs. Flame shells bind small stones into nests which can accumulate over time into biogenic reefs. The associated biodiversity is high and flame shell beds are classed as a priority marine feature (PMF) and are named in the UK Biodiversity Action Plan. When beds are encountered during electrical cable route-planning this can lead to significant delays and cost increases and potential re-routing. However, rather little is known regarding *L. hians* ecology and its ability to recover from disturbance. Knowledge of recovery rates is currently based on a single scientific study although that was focussed on disturbance resulting from scallop dredging. It is unclear if mitigation for smaller-scale disturbance, such as resulting from cabling, could be successful. For example, the potential for the temporary removal of nests during cable entrenching followed by reseeding after cable burial has not been investigated. This PhD is aimed at improving basic ecological knowledge of flame shells as well as testing some potential mitigation options. The overall aim is to improve the scientific knowledge base with regard to the management of this important benthic species when encountered in renewable energy developments
UHI	01/10/2018	**H2GEN - Hydrogen for the Agricultural Sector**	The objective is to assess the economics of the use of stranded or curtailed electricity to produce hydrogen and develop innovative solutions focussed on the reduction of cost of the electrolysers. This will then be applied to the development of systems which will use the hydrogen to produce ammonia and green fertilizer. The project will look at ways cost can be reduced at each stage (particularly in the electrolysis stage) by investigating state-of-the-art innovation in this sector. Objectives are: 1. Research into the costs of all stages of ammonia fertilizer production using renewable energy sources with a particular focus on the high cost of electrolysis. 2. Propose and develop a prototype model for a small-scale low-cost electrolyzer if economically viable 3. Decarbonise the agricultural sector - support 'green farming' including the use of hydrogen and/or ammonia to power farm machinery 4. Develop the concept of autonomous farming powered by hydrogen Farms generally have a lot of land available for renewable energy generation, but limited grid connection capability. This analysis could establish the proof-of-concept and the research carried out with regard to the development of an innovative electrolyzer technology will be globally advantageous for everyone.

Lead Institute	Start Date	PhD Title	Project Summary:
UHI	01/10/2018	**Optimisation of data for use in planning marine developments**	The project will be to design a model which can integrate available data to inform the siting and design of marine developments (e.g. subsea cables, marine renewables) leading to a model which can assess 'best outcome' based on economic, socio-cultural and environmental outcomes. The model would provide a framework to plan detailed site-level positing of infrastructure whilst taking into account development risk incorporating best economic layout for the developer but also managing risks in terms of impacts on other interests (e.g. uses, users and environment). The model would help to reduce development risk by ensuring detailed planning considers broader impacts and consideration beyond those which are economic return for the developer. This will help to provide an evidence base for the developer and decision-makers that any proposal will offer the best outcome for all users and uses. Additionally, the model could be used to assign confidence to data sets to allow confidence in different scenarios to be assessed, therefore highlighting where new data-gathering could further reduce uncertainty and risk. This approach could help to reduce the cost to the marine renewables sector through expensive delays and objections, in addition, it could offer wider societal benefits through enhanced co-use and co-location.
UHI	03/12/2018	**Quantification of seabird use of tidal environments: Novel methods to address potential biases in vantage point survey data**	Regulators need to quantify the distribution of seabirds to understand the potential for interactions with tidal energy developments, and any negative effects that may result from these interactions. A widely used technique for such site characterisation is Vantage Point surveys from the shore. However, the ability of such data to inform impact assessments or monitor for post-construction effects can be compromised by the reduction in detection probability with increasing distance from the observer, confounded by coincidental gradient with distance from the coast. This can result in biases in the data. The usefulness of the data may also be limited by rapid tidal flow at the study locations producing a flux of birds past the observer, rather than an instantaneous snapshot of occurrence. This may result in artificially inflated abundance and therefore affect estimates. The PhD would improve the knowledge base available to industry and regulators, reduce consenting risk, and have the potential to reduce costs. The research will investigate methods to address the limitations through developing data collection protocols, data analyses techniques, and model simulations. The project will have links and synergies with the UAV project also submitted in this call for proposals.
AFBI	01/10/2018	**Renewable energy crops for reducing agricultural run-off and improving water quality**	To achieve changes in agricultural practice required for bioenergy implementation and sustainable land management, the impacts of proposed measures must be understood so there is solid scientific evidence regarding the sustainability of agricultural outputs, and effective, straightforward recommendations can be given to farmers. There is ongoing field research at AFBI investigating the efficacy, applicability and nutrient management potential of different site management techniques, with the recent inclusion of strategically positioned SRC willow to protect against diffuse pollution into the environment. Following on from this research, this PhD project aims to (i) utilise data from the field trials to investigate the effectiveness of renewable energy crops for meeting renewable energy targets, reducing agricultural run-off and improving water quality, (ii) develop a model to analyse the impact of such systems on a wider scale and make recommendations for agri-environmental policy. The model will take account of both spatial (e.g. characteristics of the receiving environment such as soil type) and temporal (e.g. weather conditions, time of the year) issues through the integration of spatial-temporal LCA (STLCA) and geographic information systems (GIS).
AFBI	01/10/2018	**Nutrient management of digestate and slurry combined with Energy recovery**	In N Ireland, 63% of water bodies are not achieving the "Good or Better" status required by the Water Framework Directive, a performance well below the EU average (47%). This is caused by both wastewater treatment and agricultural pollution, where runoff from intensive slurry and dirty water land application, as well as legacy soil P, are major contributors. Slurries and dirty water are commonly used as fertiliser in bioenergy plantations. In addition, an expanding anaerobic digestion industry will result in increased production of digestate, which is typically land-spread and associated with similar environmental problems to slurry. New management practices are being driven by the DAERA commissioned report, *"Delivering Our Future, Valuing Our Soils: A Sustainable Agricultural Land Management Strategy for Northern Ireland"* (SALMS), which made recommendations for reducing risks to water quality, including appropriate redistribution of slurries/derivatives and on-farm phosphorous separation. The use of mechanical separation technologies to separate digestate/slurries into solid and liquid fractions is an option to partition nutrient, water and fibre, and as result facilitate higher value utilisation of these materials in order to meet the farmer's and the environment's needs. This project will investigate (1) Separation, (2) Fraction Characterisation, and (3) Solids Reuse focusing on Combustion.

Lead Institute	Start Date	PhD Title	Project Summary:
LyIT	01/11/2017	**Transitioning towards socially acceptable use of the Marine Renewable energy in Ireland and Northern Ireland (working title)**	The potential for Ireland and Northern Ireland to become leaders in the field of Marine Renewable Energy (MRE) has long been highlighted in government documents. The experience of the onshore renewable energy sector highlights the fact that enhancing the social acceptability of MRE will play a major role in realising this potential. Social acceptability is understood as: community acceptance; market acceptance; and socio-political acceptance. Using the emerging field of energy transition studies, this project will: a) examine the factors that impact on the acceptability of MRE in Ireland and Northern Ireland.; b) working with industry and government, the project will develop and test transition pathways which will enhance the acceptability of MRE; and c) develop social acceptability guidelines which can be implemented by industry and local government. A key question in the development and implementation of new technology is the extent to which factors leading to its success (drivers or enablers) or failure (barriers or disablers) can be identified and changed or removed (Gichoya, 2005; Neij and Astrand, 2006; Baxter and Sommerville, 2010; Kamp, 2010; Wieczorek et al., 2015). The thesis will examine whether policy incoherence and poor community acceptance are or will potentially inhibit the development of marine renewable energy in Ireland and Scotland. It will also address the economic impact of not delivering on our international commitments to a more neutral economy
LyIT	01/10/2018	**An offshore wind turbine mechanical-power electronic coupled fault diagnostic tool**	Stops (i.e. grid issues), downtime (i.e. failures relates to sub-systems, assemblies and subassemblies) and fault diagnostics are available for onshore wind turbine and farms collected over the last twenty years in both the USA and Europe with some further, but sparse offshore data available. Onshore failure rates and downtime indicates that electrical systems have the highest failure rates and that gearboxes cause the longest downtime per failure. In addition 75% faults caused 5% downtime and 25% faults caused 95% downtime. Annually, 1 to 3% of turbines require blade replacements with spikes in years 1 and 5. About 2% of turbines per year (through 10 years of operations) require blade replacements; lightning strikes are the most commonly noted cause of failure. Average gearbox failure rate over 10 years of operations is estimated at 5%, peaked in years 4, 5 and 8. The average generator failure rate is somewhat lower and over 10 years of operations is estimated at 3.5%, peaking in years 6 and 7. An accurate understanding and effective management strategy of offshore wind turbine stops, downtime and fault diagnostics is critical for optimum operation and maintenance so that the turbine realises its full asset potential. The aim of this project is to fully profile stops, downtime and fault diagnostics of offshore wind turbines in order to 1) build a comprehensive outage database and 2) design an innovative, proactive rather than reactive mechanical-power electronic coupled fault diagnostic tool to ensure a robust long term financial return for investors, owners and operators.
LyIT	01/10/2018	**Modelling the dynamic response of floating solar PV arrays to develop the basis of sustainable design**	Floating solar PV arrays is a rapidly expanding industry doubling in size each year. The present World installed capacity is now in excess of 100MW and yet design codes and standards have still to be developed. All current installations are in very sheltered and shallow waters such as reservoirs and relatively small inland lakes. If the technology is to be used in estuaries and nearshore coastal areas a lot more needs to be understood about dynamic loading from wind, wave and currents along with the development of the necessary design tools. This will include the coupled analysis of the moored structure including the anchoring system. There are multiple challenges in economic and sustainable platform design, survival in harsh marine environments, insurance which requires classification and development of other markets outside electrical production for grid supply. The student will work alongside a team undertaking both numerical and physical modelling as well as access data from a 30kW test module which is being built as part of another project. The primary emphasis is on total system modelling to gain a better understanding of environmental loading in coastal and nearshore locations which will contribute to bespoke design codes for this industry.

Lead Institute	Start Date	PhD Title	Project Summary:
LyIT	01/03/2019	**Development of novel photocatalytic materials and technology for aquaculture water treatment**	*Aquaculture is a prominent area of industry in Ireland, Northern Ireland and Scotland. The presence of chemical contaminants, however, can cause* significant disruption resulting in financial loss. A major issue is a quick uptake of these compounds by fish, which therefore means there is a significant challenge to ensure their rapid and efficient removal. Furthermore, the growth of biofilms and the accumulation of other materials can lead to fouling issues in nets and structures in marine fish farms. Photocatalysis has become an attractive method for achieving environmental remediation due to its ambient operating conditions, minimal maintenance and running costs. The process is driven by the absorption of light which generates powerful radical species capable of pollutant removal. A current challenge is the integration with existing technologies and renewable energy. A project has already been established on the coupling of photocatalysis with floating solar photovoltaic (PV) panels for the removal of contaminants in fish farming as an energy-efficient approach (Clare Rice, QUB). The focus of this project will be on the development of novel photocatalytic materials and their deployment in materials such as netting and fibreglass sheets and films for removal of contaminants from water which is of concern to aquaculture companies. Following discussion with an aquaculture company in Ireland, a particular challenge that was identified was fouling of nets and structures in marine fish farms. The applicants have previously demonstrated through an initial proof of principle research that photocatalysts can be effective at addressing biofouling encountered in fish farming applications and hence this will be a primary focus of the project. Furthermore, the team at QUB have previously demonstrated the applicability of photocatalysis for removal of chemicals of concern to the fish farming sector including chemical treatment for parasites and removal of compounds such as geosmin which has caused taste taint problems for fish farms in the Netherlands and the US. Other chemical contaminants of concern which may accumulate in the fish will be investigated. Currently as an organic producer, Marine Harvest cannot use antifouling for nets or structures. This necessitates removing nets and washing them in purpose-built washing machines which are powered by diesel generators. Reducing the need for washing nest will, therefore, contribute to the reduction of carbon emissions and will also have a positive impact on the fish as they will not be stressed or disturbed due to interventions currently needed for washing.
QUB	03/01/2018	**Adding value to the G-Waste stream to produce renewable fuels and chemicals**	We propose to develop an integrated process for catalytic up-gradation of G-waste stream into valuable products such as glycerol esters as fuel additives and bio-diesel as fuel. The G-Waste stream is a valuable waste biomass resource available to G100 ePower Ltd (120 million litres per annum), forecast to grow steadily. The G-Waste stream is the waste stream generated from biodiesel production from vegetable oils and consists of 65-70% glycerol and 30-35% fatty acids. In this PhD project, we propose to develop integrated catalytic processes in two work packages to add value to the G-Waste. Work packages will be: WP1: Glycerol acetylation to produce glycerol esters, glycerol monoacetin and diacetin, which can be blended into bio-diesel produced in WP2 to enhance the cold flow properties, increase cetane number and reduce the noxious gas emissions. In QUB, we have developed proof-of-concept using novel OMS2-ZSM5 hybrid catalyst, showing promising results and TRL of 2-3 has been achieved. Non-Confidential WP2: Selective hydrogenation of fatty acids to alkanes: In QUB, we have recently developed novel low-temperature technology for hydrogenation of fatty acids to alkanes with near 100% selectivity to produce bio-diesel and TRL level of 3-4 has been achieved. Both WP1 and WP2 will be integrated, and glycerol esters produced in WP1 will be blended into biodiesel produced in WP2, to improve the fuel quality. Exploratory WP3: Further to above work packages; on the exploratory basis with the help of Meng project, we will study photo-reforming of glycerol to produce H2. In QUB, we have promising results both in batch and continuous flow to produce hydrogen from glycerol and TRL level of 1-2 has been achieved. This hydrogen can then be used into WP2 for sustainable reduction of fatty acids to biodiesel. This work fits with the theme of bioenergy and will benefit the entire sector based on the biorefinery concept to achieve sustainability. This also fits into sustainable energy PRP in QUB. The integrated catalytic processes technology developed herein has the potential for commercialization with our industrial partner G100 ePower Ltd.

Lead Institute	Start Date	PhD Title	Project Summary:
QUB	01/02/2018	**Extraction of Biofuels from Residual Lignocellulosic Biomass from Anaerobic Digestion**	In Northern Ireland alone there is an estimated annual generation of 150,000 tonnes of solid lignocellulosic digestate as a byproduct of Anaerobic Digestion. While the bio-methane has a value either currently for electricity generation or as a potential fuel for transport, issues remain in terms of what is done with the residual digestate. Previously our group has been able to extract value-added chemicals through the valorisation of biopolymers (lignin and suberin) from highly fibrous low-value plant materials, particularly wood bark. The compounds isolated from this processing can be isolated to provide higher added-value materials and intermediates, including biofuels. Previously, the catalysts used for this process had a relatively short lifetime, and so part of the project, based on our extensive previous work in the field of catalyst stability/regeneration, will be the investigation of stabilisers to prolong the longevity of the catalyst, making such processing even more feasible. The impact of the project will be the establishment of residual digestate from AD as a feedstock for biofuels. Ultimately, this will make AD plants more profitable, through the added value of the digestate, while simultaneously reducing the waste disposal problems of the digestate residues. This project has the potential to provide a complementary and sustainable supply chain of biofuels for the local economy
QUB	03/01/2018	**Lithium battery Energy Storage for transport and Stationary Renewable Bio-Energy Lithium battery Energy Storage for transport and Stationary Renewable Bio-Energy**	Project Aims • Improving the lifetime of lithium-based batteries • Investigate and understand degradation mechanisms • Apply to stationary and transport energy storage technologies both land-based and marine (marine hybrid drives) • Introduction of decentralised power generation and hybridised / EV transport to reduce carbon and emissions will dramatically increase the need for improved battery storage. The Challenges Facing Battery Technology in the Industry Battery state of health (SOH) monitoring has become a crucial challenge in stationary storage, hybrid electric vehicles (HEVs) and all-electric vehicles (EVs) research, as SOH significantly affects the overall vehicle performance and life cycle. The battery life cycle is critical from a cost, market acceptance and sustainability perspective. Extensive research is being done on the physics of degradation mechanisms/failure modes but this often involves destructive techniques. One challenging research area is can we now get these measurements into the cells without destroying them with a view to utilising the data obtained as part of the battery management system. *PhD Theme* • Investigating the use of spectroscopic techniques for *in situ analysis* of battery degradation HORIBA has numerous application scientists who understand these techniques and can impart this knowledge to the PhD student so that they can apply them to the automotive battery problem
QUB	01/12/2017	**Quantifying the impact of marine renewable energy devices on harbour seals: a multifaceted approach to plugging knowledge gaps on fine-scale habitat use in a tidally active environment.**	Collision risk to harbour seals is currently the key environmental constraint on tidal energy development and test sites in the Pentland Firth, Orkney Waters and Strangford Lough area, where this species is known to be in decline. In Strangford Lough, the harbour seal is the species of greatest interest, as this population is the only marine mammal noted as a qualifying feature of the Strangford Lough SAC. The Lough is spatially heterogeneous with high and low current flows; it is the location of SeaGen and is currently a test site for Minesto's DeepGreen kite. Therefore, Strangford Lough is an ideal site for assessing environmental interactions of tidal energy devices with harbour seals. By integrating existing data with data gathered during the course of the project, the student will advance the collision risk framework that is currently being developed at QUB. Collectively, this research will reduce scientific uncertainty surrounding this key issue by providing new insights to improve the estimates of collision risk to harbour seals from tidal energy devices. This information can be used to better assess the consequences for these protected populations in Scotland and Ireland, with the aim of expediting the consenting process.

Lead Institute	Start Date	PhD Title	Project Summary:
QUB	01/12/2017	**Addressing the emissions of the bio-energy economy**	In Northern Ireland, there has been a significant increase in Biomass heating due, in the main part, to the renewable heat incentive with ~ 2,100 wood chip and pellet-burning boilers installed in recent years. Additionally, utilisation of natural gas and biomethane from anaerobic digestion (AD) is rapidly developing as a major energy source, with industrial plants (such as Bombardier and Montupet) installing their own engines and using these fuels to supply heat and/or power. With 17% of PM2.5 in London coming from wood-burning and gas-burning contributing 38% of the NOx, the current lack of strict emissions regulations for these energy sources will change. This project will address the emissions issues surrounding biofuels such as wood chip and biomethane through better defining the pollutants and investigation of catalyst technologies to remediate these emissions. Combustion testing will be conducted at AFBI while catalyst development and testing will be at QUB, UHI will perform a sensitivity analysis of the combustions and design of experiments (DofE) to guide the catalyst development. The most promising catalyst(s) will be transferred for in-situ testing at AFBI. The project will also inform public knowledge of the impact of such biofuels on air quality.
QUB	01/03/2018	**Fatigue assessment of composite blades of offshore wind turbines**	In recent years, offshore wind turbines with higher output power (10 MW) are getting more and more popular for generating more energy. On the other hand, offshore wind turbines are exposed to between 108 and 109 load cycles during their operation time and they are subjected to the simultaneous action of the wave, current and wind loads. Aerodynamic and hydrodynamic damping and excitation loads are highly coupled which require integrated analysis of the structure considering the misalignment of wave and wind loads. The stochastic nature of wind and wave results in stochastic nonlinear loads that can excite Eigen frequencies of the system such as blades, tower as well as natural frequencies of the substructure. In particular, as blades of wind turbines are slender structural elements that are normally made of composite, the aero-elastic consideration is the key feature in the design of wind turbines
QUB	01/03/2018	**Numerical method for Dynamic Analysis of Offshore Renewable Energy(ORE) devices**	The role of the mooring system of ORE devices is to keep the devices on station for the entire lifetime while maintaining mooring tensions are within acceptable limits. Mooring lines fatigue and failure are the most critical point of moored ORE devices. The failure of mooring system is the biggest challenge for the designers, manufacturers, operators, installation contractors and classification societies. At the design stage, suitable mooring configurations may prevent failure after deployment of the device. The mooring design is basically different for Motion Independent Devices such as WEC and Motion Dependent Devices such as OWT. So, the type of ORE device and the characteristics of the deployment area shall take into account to design a mooring system. Also, in dynamic analysis, the majority of external loads are originating from the combined effects of wind, wave and current flow and tide height variations. Therefore, some non-linear effects should be considered to have an optimal design: 1. The non-linear behaviour of new materials (synthetic ropes, the Exeter Tether, etc.) 2. The non-linear hydrodynamic forces due to multi-bodies interactions in array and mooring lines interactions 3. The non-linear loads (higher-order wave loads (i.e. second-order wave excitation), vortex-induced vibration due to current load and non-linear viscous fluid damping load) 4. Geometric mooring line non-linearity in an array It is more cost-effective to consider all of the aforementioned non-linearities in the dynamic analysis of design due to the prevention of failure after deployment. But the existing commercial mooring system design software cannot fully represent all of these non-linearities. A new numerical approach will be developed in dynamic analysis to overcome the deficiencies and get the optimal design of the mooring system.
QUB	01/10/2018	**Novel combined energy cycles utilising renewable working fluids for efficient energy conversion**	Renewable refrigerants are attracting increased scientific and industrial attention for several environmental reasons. Amongst these is a commercial product (R723) consisting of a 60:40 (wt%) blend of ammonia (NH_3) and dimethylether (DME). This mixture is not only environmentally friendly, energy-efficient, and readily available but can be produced easily using renewably derived hydrogen (i.e. by CO_2 and nitrogen hydrogenation). Furthermore, this product combines ammonia's energy advantages with the oil miscibility of DME. Interestingly both materials are being investigated as bio-fuels for a variety of applications. While they have been shown to lower carbon and particulate emissions, increased NOx has been linked to the combustion of NH_3 in normal IC engines. However alternative energy conversion technologies such as solid oxide fuel cells (SOFC) offer the opportunity to convert NH_3 and DME efficiently to electrical energy at high efficiency (>65%). By combining these circuits, it thus becomes possible to develop a cycle whereby the fuel and refrigerant are one in the same leading to self-contained units with increased efficiency in refrigeration and/or heat-pump applications. This project will build upon external and internal expertise in the thermodynamics of organic rankine cycles and SOFC design to develop and test this novel combined cycle. Two students are requested to work as a combined team
QUB	01/10/2018	**Recovery of waste heat from refrigeration cycles**	

Lead Institute	Start Date	PhD Title	Project Summary:
QUB	01/10/2018	**Investigating the coupling of photocatalytic technology with floating solar PV arrays for aquaculture water treatment**	Aquaculture is a prominent area of industry in for both Scotland and Northern Ireland. The presence of chemical contaminates, however, can cause significant disruption resulting in financial loss. A major issue is the quick uptake of these compounds by fish, which therefore means there is a significant challenge to ensure their rapid and efficient removal. Photocatalysis has become an attractive method for achieving environmental remediation due to its ambient operating conditions, minimal maintenance and running costs. The process is driven by the absorption of light which generates powerful radical species capable of pollutant removal. A current challenge is the integration with existing technologies and renewable energy. Therefore, this project proposes the coupling of photocatalysis with floating solar photovoltaic (PV) panels for the removal of contaminates in fish farming as an energy-efficient approach. To achieve this, crucial challenges must be overcome; integration of photocatalysis with floating PV panels or additional hybrid renewable energy, rapid removal of contaminates, versatile design for the deployment of the unit and removal of a range of pollutants. This project has been designed to be conducted in collaboration with proposal 31, which contributes to the interdisciplinary nature of the Bryden Centre. Both projects are, however, capable of operating independently should only one be funded at this stage
QUB	03/12/2018	**Optimal integration of joint energy and power services to determine true strike price of offshore wind**	Industry Problems / Challenges: Offshore wind farms should, like other generators, contribute to supporting all power system operations. This should technically, financially and economically place offshore wind power on the same level playing field as fossil fuel generation in terms of the delivery of joint energy and power services to the grid, opening revenue streams for wind farm owners that reduce and eventually eliminate dependence on support mechanisms, subsidies and feed in tariffs. Joint energy and reserve markets or primary frequency response services for renewable energy are discussed by Gonzalez et al (2014) and Foley et al (2013). The key challenges are (i) to find an optimal way to design the necessary joint markets or energy and ancillary services, allowing offshore wind power (and other renewables or demand response more generally) to declare their ability to support power system operation, though under uncertainty; and (ii) to define optimal offering strategies for offshore wind farm operators in such markets. This calls for a practical optimisation tool that fully accounts for wind forecast uncertainties, regulatory and market constraints, strategic behaviour of the market participants, opportunities for storage and operational reliability constraints involved in power system operations. The aim of this project is to develop a realistic offshore wind market cost optimisation model of the UK and Irish electricity markets in PYOMO. PYOMO is a collection of open-source optimization-related Python packages that supports a diverse set of optimization capabilities for formulating and analysing optimization models. PYOMO is open source, thus the model of the SEM and BETTA will be freely available to all, unlike the existing models which require access to proprietary software. This is cost-prohibitive for many academics and companies. The model will capture the mathematical complexity of the Irish and Great Britain (i.e. SEM and BETTA) wholesale electricity systems. These markets will be analysed as a comparative test system to predict the true strike price of offshore wind and place a value on the services that offshore wind can provide to the power system.
QUB	03/12/2018	**Thermochemical Conversion of Biomass Lignin into Mesoporous Carbon Materials**	There is a global imperative towards replacing conventional fossil feedstocks with green resources such as biomass. Within the three main components of biomass, lignin is a typical recalcitrant component; it is also a promising precursor for preparing mesoporous carbons aiming for industrial applications, such as biomedical devices and energy storage. This project is to address the global challenge with, particular emphasis on efficiently utilising the biomass lignin to produce mesoporous carbons with specific pore structures. This project is multidisciplinary thus both multi-scale simulations (Quantum Chemistry, System Modelling, and Techno-economic Analysis) and experimental validation will be carried out. The project has been well-designed by involving both industry and academia within UK and abroad: QUB will be the leading institution with contribution on multi-scale modelling led by outstanding researchers (Dr Zhang, Prof Rooney, Dr Nockemann); Industrial support from Premier Green Energy (Mr O'Grady), Republic Ireland, will be crucial in providing experimental feedstock and facilities as in-kind contribution. The project will also gain support from the University of Strathclyde (Dr Li) by bringing in expertise on CFD modelling. Chinese Academy of Forestry (Prof Liu and Prof Jiang) will also highly support the proposal by providing the experimental testing facilities as an in-kind contribution.

Appendix IV – NWCAM Examples of Stakeholder Engagement

According to the NWCAM project partners, the details below offer an indication of the softer contribution of Catalyst team to the NWCAM project in terms of consortium building and developing new and exciting relationships. The document is sectioned into activity per quarter.

April to June 2018	• IMC 35 DIT, Smart Health NI, Digital DNA. Invest NI & Innovate UK conference, Accelerate your Growth. • Attended Ulster University's Festival of PhDs, Magee campus, NWCAM PhD Richard Ward won the best poster. • Attended Lean Launch final pitches Ulster University & QUB. • Participated in NI Manufacturing Task Force workshop, Antrim. • Attended a variety of industry awards dinners including CBI, Chartered Institute of • Engineering, Irish News Awards, Invent Semi-Finals, variety of Chamber of Commerce events in Belfast and Derry, Royal Academy of Engineering, Intertrade Ireland Horizon 2020 dinner, funding updates. • Exhibited at IT Sligo Engineering Expo, LyIT Engineering expo.
July to September 2018	Outlined below are all the conferences, events and meetings attended during July 2018 to September 2018: • Catalyst Frameworks held at KPMG on 09/08/2018: Dr Dan Crawford from axial3D on the panel of speakers; • 9th Annual Translational Medicine Conference City Hotel, Derry/Londonderry, 12th - 13th September 2018; • Meeting with Proaxsis to discuss future NWCAM opportunities 07/07/18; • Meeting with QUB Graduate School, Claire Harris to intro NWCAM 08/08/18; • Meeting with SWC, Alastair Quinn to discuss Interreg projects, shared learnings and discussed potential synergies 14/08/18; • Meeting with Manufacturing NI, Stephen Kelly to discuss NWCAM research projects, survey and Future of Work 2019 opportunities; • Meeting with UU, Dr Shirley Davey, Health-NI, Elaine Colgan, Neil Goodwin on 22/08/18 to discuss NWCAM research projects, survey and opportunities for our partners to explore; • Had an introductory call on 23/08/18 with Enterprise Ireland, Dr Eithne McShane to intro NWCAM; • Conference call with Highlands & Islands, Fiona Fraser 04/09/18 to discuss NWCAM and coloration opportunities; • Call with Science Foundation Ireland, Yvonne Halpin, 06/09/18 to discuss NWCAM and set up mtg with wider teams; • Attended QUB & UU 3 min PhD pitches, 06/09/18, Ulster Museum; • Meeting with Take Ten, Fintan Gamble, 07/09/18 to discuss potential future collaborations; • Meeting with Neurovalens, Dr Jason McKeown,10/09/18 to discuss potential future research project collaborations; • Attended the R&D tax credits Catalyst Frameworks with Amplifi Solutions, 12/09/18 – shared info with industry partners; • Visit on 14/09/2018 to Prof Dennis Dowling, Director of I-Form, UCD to introduce the NWCAM team and discuss potential synergies and collaborations; • Meeting with Dr Eithne McShane, Enterprise Ireland, East Point, Dublin to discuss NWCAM, funding options and Life and Health Science Industry Survey; • Meeting with Chris Trotter, Clarendon Funds, 18/09/18 intro NWCAM and good to learn about private funding NI ecosystem; • Attended Innovate UK/ Digital Health Workshop 19/09/2018 at NIBEC, UUJ; • Attended QUB Startup Festival, met up with Stephen McComb, KTP, 26/09/18 • Attended Medical Technology Ireland, Galway Racecourse, 26-27 September 2018; • Attended 300sec Female Entrepreneur pitches at The Portershed, Galway on 26/09/2018 run by Mary McKenna (previously an Entrepreneur in Residence at Catalyst); • Attended Innovation Nation, Newry, 27/09/2018; • Attended Denroy Autumn Lecture entitled "The History and Development of Plastics" by Dr Brenda Keneghan, Victoria and Albert Museum on 03/10/2018.

<table>
<tr><td>October to December 2018</td><td>Below outlines all the meetings, conferences and events attended during October 2018 to December 2018.

• Met with Charlie Tuxworth, Equiniti, Commercialisation consultant, 08/10/18.
• Met with Michaela Murphy, Scientific Advisor, Department for International Trade (DIT),
• British Embassy, Dublin, 10/10/2018 to discuss NWCAM/Catalyst collaborative opportunities and DIT support. Agreed that Michaela will visit Catalyst in early 2019. Follow-up invitation from Michaela to a MedTech event hosted by DIT/CURAM at NUIG on 28 February 2019;
• Met with Dr Michael Flynn, Dr Yvonne Haplin, SFI, Dublin, 10/10/2018. Follow- up communications re taking part in panel assessment of Small Grant Awards, Fintech hub connections and a potential visit to Catalyst in early 2019;
• Attended Invest NI/Innovate UK event on Funding for Innovation in Life & Health Sciences, 23/10/2018;
• Attended InterTradeIreland Innovation Workshop, QUB, 24/10/18 – LPE also in attendance with 10-15 NI companies.
• Met with NITC, QUB, Colm Rice, discussions about AM expertise and NWCAM research projects, 24/10/18
• Attended Frameworks workshop, Start-up Fundamentals, 75-100 attendees, local NI companies, 25/10/18.
• Met with Qubis (QUB spinout companies) Chairman Colin Reid, discussions about NWCAM and QUB spin-out companies, 30/10/18.
• Met with VC Clarendon Fund, Director Jim Curran, 30/10/18
• Invest NI, Vicky Kell Innovation, Research & Development, discussions about NWCAM research projects and Future of Work project with Nuprint, 12/11/18.
• Future of Work conference 2019 - engagement with some of our NWCAM industry partners e.g. Nuprint who are interested to participate in the Automation case study;
• Hosted visit by Dr Kieran Ryan, Commercial Manager, NUIG on 12-13/11/2018 to meet with Catalyst, Ulster University and Queen’s University and discuss opportunities for collaboration/synergies; Visit by the NWCAM team to NUIG to be arranged.
• NZ Maori delegation, presented NWCAM to a variety of companies, government officials including Callaghan Innovation, NZTE, IDA, 14/11/18.
• Conference call with John Cunningham, Business Development Manager, CURAM, a SFI centre designing the next generation of ‘smart’ medical devices”. Discussions re collaborative opportunities and synergies. Agreed that John will visit Catalyst on 14 February 2019.
• Conference call meeting with Dr Toby Williams, CALIN (Celtic Advanced Life Science Innovation Network) – one theme is ‘Devices and Biosensors’ /Industry 4.0 is a key driver strong connection with CURAM. Discussions re collaborative opportunities and synergies. Met Toby Williams at CURAM MedTech event hosted by DIT on 28 February 2019;</td></tr>
<tr><td>January 2019 to March 2019</td><td>• Attended IBIOIC conference at Univ of Strathclyde, 30-31/01/19:

- Disseminated presentations to NWCAM partners:
- Follow up with Julia Brown from Scottish Enterprise – article with L&HS survey subsequently published in Life Science Scotland website about Glasgow projects with Nuprint and Causeway Sensors;

• Attended Manufacturing and Supply Chain Exhibition, Belfast 13/02/2019 – Disseminated presentations to NWCAM partners.
• Attended MedTech event hosted by DIT/CURAM at NUIG on 28/02/19; Disseminated presentations to NWCAM partners. Useful contacts from the meeting included:

- NHS- Dr Linda Magee- NHS Investment specialist, DIT
- Sinead Keogh- Director of MedTech & Engineering Sectors, IBEC
- Shirley McCay, DIT
- Matt Moran- Director of BioPharmChem Ireland
- Prof Chris Lowe- Director of Cambridge Academy of Therapeutic Sciences (CATS).

• Attended Anchor High Summit 12-13/02/19. Disseminated presentations to NWCAM partners:</td></tr>
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	- Follow up meeting with Adrian Johnston, Director of Digital Catapult NI (DCNI) and Sue McGuire, BD Manager at Digital Catapult NI, Ormeau Baths, Belfast at end of March; DCNI help companies to adopt disruptive/emerging technologies i.e. AI/Machine learning, future networks, Low powered wide area networks (LPWANS) and immersive/VR/AR; - Interested in working with two sectors: Creative industries & Manufacturing. Working with Denroy and Nuprint already and made an introduction to Causeway Sensors; Note: As a follow up from Anchor High Summit, DCNI shall run a workshop for manufacturing companies including NWCAM industry partners 16 May; NWCAM industry partners have been advised of this workshop; • Meeting with Diane Dundas from CO-Innovate- Diane indicated that she is happy to facilitate a meeting with any NWCAM company if any interest. Note axial3D and IT Sligo have already submitted a funding application; • Meeting with Tom Verner, The Momentum Group, Bangor on 27/03/19- R&D Tax Credits connected with local patent attorneys; • Meeting with Malcolm Harold KTN- Digital Manufacturing. High-Value Manufacturing Catapult (HVMC) and Knowledge Transfer Network (KTN) are mapping capabilities of UK's Industrial Digitalisation Technologies (IDTs**) on behalf of the Made Smarter Review and Innovate UK. The mapping shall help signpost Small to Medium-sized Enterprises (SMEs) to regional support and help facilitate mentoring, focused projects, placements and workshops. Sent to all NWCAM Partners. • Meeting with Declan McDevitt, Digital Solutions Manager and Alan Norbury, Chief Technologist from Siemen at Anchor High Summit and subsequently introduced Declan to Dr Justin Quin. JQ to meet with Declan in April 19. • Introduced Dr Mark Farrall, Siemens Industry Software Computational Dynamics Ltd, Digital Factory Division who may be a useful contact for Armstrong Medical. • Meeting with David Branagh, CHIC NI – 07/02/2019 • John Cunningham (JC), CURAM, (Centre for Research for Medical Devices) Global Centre of Excellence visited Catalyst HQ, 14/02/2019. CURAM is funded by SFI €37.1m with €12.5m from industry. They have leveraged 57.4mil, have 28 industry partners. Key interests lie in biomaterials and device design/ cardiov/resp/neural/muscloskeletal/renal/uroloegy/softtissue/ tissue engineering/ regenerative medicine - John highlighted that they are part of the Interreg program -Codex4SMEs- Companion Diagnostics & Data Analytics- - NW Europe. There will be an Interreg codex event in September bringing company start-ups in biomarkers in vitro and diagnostics with VC and larger pharmaceutical companies in Galway. Information re the event to be disseminated to NWCAM partners upon receipt from JC; - Also noted the BioInnovate program at CURAM run by Dr Paul Anglim- strategic lead. Similar to Co-Founders but runs as an Industry fellowship program for 10 months with approx. 3 teams. Areas of interest are in Oncology /Orthopaedics /Neurovascular. Sponsored by SFI and industry. • Meeting with Lorraine Acheson, Innovate UK 14/02/2019; Highlighted some upcoming funding calls which may be useful for our NWCAM partners; • Meeting with Harry O'Rahilly, Prosperity & Economy, Europe Directorate, Foreign & Commonwealth Office; economic co-operation and development- helps identify potential collaborations and conducting policy analysis to help DIT colleagues with Trade and Investment wins.

Appendix V – BREATH Project Publications

Conference Presentations	1. Keith Thornbury, Lorraine Martin, Eamonn Bradley, Mark Hollywood, Gerard Sergeant, Noel McHale. Contractile effects of NaV1.5 current in rabbit bronchial smooth muscle. European Respiratory Journal 2017 50: PA1806; DOI: 10.1183/1393003.congress-2017.PA180. https://erj.ersjournals.com/content/50/suppl_61/PA1806 2. Nicholas D. Mullins, S. Dudem, G.P. Sergeant, K.D. Thornbury, S. Roy, R.J. Large, E. Bradley and Mark A. Hollywood (2017). Design, Synthesis And Structure-Activity Relationships Of Large Conductance Ca2+- Activated K+ (BK) Channel Modulators. "Recent Advances in Synthesis and Chemical Biology XVI" symposium University College Dublin, Ireland 3. Nicholas D. Mullins, S. Dudem, G.P. Sergeant, K.D. Thornbury, S. Roy, R.J. Large, E. Bradley and Mark A. Hollywood. (2018) Discovery and Development of Large- Conductance Ca2+-Activated K+ (BK) Channel Modulators. Technology & Innovation Centre (TIC), University of Strathclyde, Glasgow, UK 4. Nicholas D. Mullins, S. Dudem, G.P. Sergeant, K.D. Thornbury, S. Roy, R.J. Large, E. Bradley and Mark A. Hollywood (2018). Synthesis and Structure-Activity Relationships of Novel Large-Conductance Ca2+- Activated K+ (BK) Channel Modulators. RSC Organic Meeting – Ireland Division. Queen's University Belfast, Northern Ireland. 5. Nicholas D. Mullins, S. Dudem, G.P. Sergeant, K.D. Thornbury, S. Roy, R.J. Large, E. Bradley and Mark A. Hollywood (2018). Design, synthesis and evaluation of amino anthraquinones: Large Conductance Ca2+ -activated K+ (BK) channel modulators. 22nd IUPAC International Conference on Organic Synthesis (22-ICOS). 6. Nicholas D. Mullins, E. Bradley, R.J. Large, V.V. Bihun, G.P. Sergeant, M.A. Hollywood, and K.D. Thornbury (2018) Investigating the role of large-conductance Ca2+-activated K+ (BK) ion channels in smooth muscle cell contraction using small molecules. "Recent Advances in Synthesis and Chemical Biology XVII" symposium University College Dublin, Ireland. 7. Nicholas D. Mullins, S. Dudem, G.P. Sergeant, K.D. Thornbury, S. Roy, R.J. Large, E. Bradley and Mark A. Hollywood (2019) Discovery, Design and Structure-Activity Relationships of Large-Conductance Ca2+-Activated K+ (BK) Channel Modulators. 3rd Liverpool-Romark Medicinal Chemistry Symposium, University of Liverpool, Liverpool, UK, 12th April 2019 8. Nicholas D. Mullins, V. Tyagi, G.P. Sergeant, K.D. Thornbury, R.J. Large, E. Bradley and Mark A. Hollywood (2019) Development of novel small molecule modulators of the calcium-activated chloride channel; TMEM16A. RSC Organic Division Ireland Regional Meeting 2019 7 June 2019. University College Dublin, Ireland 9. Nicholas D. Mullins, V. Tyagi, G.P. Sergeant, K.D. Thornbury, R.J. Large, E. Bradley and Mark A. Hollywood (2019) Ion Channels as Drug Targets: Design, Synthesis and Structure-Activity Relationships of Small Molecule Ion Channel Modulators. International Symposium on Synthesis and Catalysis 2019, 03-06 Sept, Evora, Portugal. Abstract Accepted 22 June 2019. 10. KD Thornbury, Victoria V Bihun, E Bradley, MA Hollywood & GP Sergeant. (2018). Effects of L-type Ca2+ blockers and the novel BKCa channel opener, GoSlo- SR5-130, on tension responses in rabbit bronchial rings. Experimental Biology Conference, San Diego, USA.https://www.fasebj.org/doi/10.1096/fasebj.2018.32.1_supplement.lb436 11. R Dwivedi, RJ Large, MA Hollywood, GP Sergeant, G Litherland & KD Thornbury. Effect of TRPC4/C5 channel antagonists in carbachol-induced contractions in murine airway. 2018, Irish Journal of Medical Science, Vol. 187, Suppl. 8, S252. https://doi.org/10.1007/s11845-018-1898-7 12. RM Matthews, E Bradley, RJ Large, L McGarvey, GP Sergeant, MA Hollywood & KD Thornbury. 2018 The role of voltage-gated sodium channels in isolated murine airway smooth muscle. 2018, Irish Journal of Medical Science, Vol. 187, Suppl. 8, 2018, Irish Journal of Medical Science, Vol. 187, Suppl. 8, S282.https://doi.org/10.1007/s11845-018-1898-7 13. Kulkarni S, Dudem S, Large R, SL Martin, J Reihill, Sergeant G, Thornbury K and Hollywood MA. LINGO proteins - novel regulatory subunits of BK channels? 2018, Irish Journal of Medical Science, Vol. 187, Suppl. 8, S282.https://doi.org/10.1007/s11845-018-1898-7 14. K Rabab, S Dudem, SL Martin, I. Tikhonova, KD Thornbury, GP Sergeant & MA Hollywood. Assessing the state-dependent effects of SR-5-6 on Kv7.4 channels expressed in HEK cells. 2018, Irish Journal of Medical Science, Vol. 187, Suppl. 8. S281.https://doi.org/10.1007/s11845-018-1898-7 15. L Morgan, MA Hollywood, KD Thornbury, L McGarvey & GP Sergeant. Prostaglandin E2 inhibits calcium oscillations in murine airway smooth muscle cells. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S283.https://doi.org/10.1007/s11845-018-1898-7 16. 1T Alkawadri, KD Thornbury, MA Hollywood[, L McGarvey, Fi Lundy & GP Sergeant Involvement of M2 muscarinic receptors in cholinergic-mediated contractions of murine bronchial rings. Irish Journal of Medical Science, Vol. 187, Suppl. 8. S249.https://doi.org/10.1007/s11845-018-1898-7

17. K. Black, A. MacKenzie, L. Dunning, A. Crilly, L. McGarvey, K. Thornbury, C.S. Goodyear, J.C. Lockhart, G.J. Litherland. Proteinase activated receptor 2 (PAR2) modulation of airway smooth muscle function. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S249.https://doi.org/10.1007/s11845-018-1898-7
18. Kirsty McCallum, Mariarca Bailo, Lynette Dunning, Marija Stankovic, Lorcan McGarvey, Mark Hollywood, Carl S. Goodyear, Anne Crilly, John C. Lockhart, Gary J. Litherland. Proteinase activated receptor-2 and autophagy regulation in airway epithelia cells. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S272.https://doi.org/10.1007/s11845-018-1898-7
19. M. Bailo, K. McCallu1, L. Dunning, M. Stankovic, J. Reihill, L. Martin, G. Sergeant, C S. Goodyear, G. Litherland, J. Lockhart1, A. Crilly. Investigating the matriptase- PAR2-ENaC axis in lung epithelial cells: potential role in COPD pathogenesis. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S249.https://doi.org/10.1007/s11845- 018-1898-7
20. Reihill, J. A., Yang, Z., Carroll, E., McGarvey, L. P., Lundy, F. T., Lockhart, J. C., Litherland, G., Crilly, A. & Martin, S. L. Evaluation of novel serine protease inhibitors to ameliorate cockroach-induced airway inflammation and cell damage. Irish Journal of Medical Science, Vol. 187, Suppl. 8, 284.https://doi.org/10.1007/s11845-018-1898-7
21. Carson, S., Reihill, J. A., Fulton, C. R., McGarvey, L. P., Lundy, F. T., Crilly, A., Thornbury, K. D. & Martin, S. L. Healthy primary epithelial cells show an elevated inflammatory response to bacterial stimulus compared to COPD cells. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S271.https://doi.org/10.1007/s11845-018- 1898-7
22. Carroll, E. L., Douglas, L. E. J., Reihill, J. A., Zhou, M., Chen, T., McGarvey, L. P., Lundy, F. T., Hollywood, M. A., Crilly, A., Lockhart, J. C. & Martin, S. L. Inhibition of ENaC activity by novel peptide trypsin-like inhibitors derived from amphibian skin secretions. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S250.https://doi.org/10.1007/s11845-018-1898-7
23. Roe, N. A., Lundy, F. T., Martin, S. L., Litherland, G., Fulton, C., Reihill, J. & McGarvey, L. Investigating TRPA1 hypersensitivity/hyperresponsiveness in a human sensory neuronal model of airway nerves. Irish Journal of Medical Science, Vol. 187, Suppl. 8, 284.https://doi.org/10.1007/s11845-018-1898-7
24. Downey, N., McGarvey, L. P., Martin, S. L., Crilly, A., Lockhart, J. C., Fulton, C., Reilhill, J. & Lundy, F. T. Isolation and Characterisation of Exosomes from Human Primary Bronchial Epithelial Cells. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S252.https://doi.org/10.1007/s11845-018-1898-7
25. Dunne, O. M., McGarvey, L. P., Martin, S. L., Sergeant, G. P., Fulton, C., Reihill, J. & Lundy, F. T. Mechanical stress induces ATP release from human primary bronchial epithelial cells. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S252.https://doi.org/10.1007/s11845-018-1898-7
26. Kelly, G. A., Reihill, J. A., McGarvey, L. P., Lundy, F. T., Litherland, G. & Martin, S. L.The secretory profile of inflammatory mediators is altered in differentiated primary COPD samples at air liquid interface compared to healthy equivalents. Irish Journal of Medical Science, Vol. 187, Suppl. 8, S272.https://doi.org/10.1007/s11845- 018-1898-7
27. Invited presentation: Martin SL. Protease inhibitors to regulate ENaC and improve airways hydration in cystic fibrosis. Session 313. ENaC and Fluid Transport across Airway Epithelial.
28. Carson S, Reihill JA, Fulton CR, McGarvey LP, Lundy FT, Crilly A, Thornbury K and Martin SL. (2019) Healthy Primary Epithelial Cells Show an Elevated Inflammatory Response to Bacterial Stimulus Compared to COPD Cells. Experimental Biology Conference, Orlando, USA. https://www.fasebj.org/doi/10.1096/fasebj.2019.33.1_supplement.127.7
29. Reihill JA, Yang Z, Carroll E, McGarvey LP, Lundy FT, Lockhart JC, Sergeant G and Martin SL. (2019) Evaluation of Novel Serine Protease Inhibitors to Ameliorate Cockroach-Induced Airway Inflammation and Cell Damage. Experimental Biology Conference, Orlando, USA .https://www.fasebj.org/doi/10.1096/fasebj.2019.33.1_supplement.127.10
30. Carroll EL, Douglas LEJ , Reihill JA, Zhou M, Chen T, McGarvey LP, Lundy FT, Hollywood MA, Lockhart JC and Martin SL. (2019) Inhibition of ENaC activity by novel peptide trypsin-like inhibitors derived from amphibian skin secretions. Experimental Biology Conference, Orlando, USA. https://www.fasebj.org/doi/10.1096/fasebj.2019.33.1_supplement.127.9
31. Kelly GA, Douglas LEJ, Maye JR, Reihill JA, McGarvey LP, Lundy FT, Litherland G and Martin SL. (2019) The secretory profile of inflammatory mediators is altered in differentiated primary COPD samples at air liquid interface compared to healthy equivalents. Experimental Biology Conference, Orlando, USA. https://www.fasebj.org/doi/10.1096/fasebj.2019.33.1_supplement.127.8
32. T Alkawadri, KD Thornbury, MA Hollywood, LP McGarvey, FT Lundy, GJ Litherland & GP Sergeant (2019) Involvement of M2muscarinic receptors and Kv7 channels in cholinergic-mediated contractions of murine bronchial rings. Aberdeen, 8-10 July 2019. https://static.physoc.org/app/uploads/2019/03/02095128/Physiology-2019-abstracts-book.pdf

	33. Invited presentation: McGarvey LP. Collaborative/networking initiatives in cough. Session: Chronic Cough in Distinct Populations. 34. A-C Devlin, OM Dunne, C Fulton, GP Sergeant, SL Martin, LP McGarvey, FT Lundy (2019) Morphological, molecular and functional characteristics of ipsc-derived sensory neurons. American Cough Conference, Washington DC, USA. (NB: Lung in press) 35. OM Dunne, LP McGarvey, SL Martin, GP Sergeant, FT Lundy. (2019) ATP release from mechanically stimulated human bronchial epithelial cells and activation of p2x3 receptors in a human sensory neuronal model. American Cough Conference, Washington DC, USA. (NB: Lung in press) 36. N Downey, L McGarvey, SL Martin, A Crilly, FT Lundy (2019) Characterisation of exosomes isolated by ultracentrifugation from human primary bronchial epithelial cells. American Cough Conference, Washington DC, USA. (NB: Lung in press) 37. NA Roe, FT Lundy, SL Martin, A Mousnier, G Litherland, L McGarvey (2019) Elucidating the role of human rhinovirus in chronic cough associated with chronic obstructive pulmonary disease. American Cough Conference, Washington DC, USA. (NB: Lung in press) 38. K Rabab, S Dudem, I Tikhanova*, KD Thornbury, GP Sergeant, & MA Hollywood (2019) GoSlo-SR-5-6 activates Kv7 channels and its effects are reduced by a F322A mutant in Kv7.4. International Kv7 Channels Symposium, 12th-14th September 2019, University of Naples Federico II, Naples, Italy. (NB: In Press) 39. RJ Large1, S Dudem1, S Kulkarni1, H McClafferty2, IG Tikhonova3, GP Sergeant1, KD Thornbury1, MJ Shipston2, B Perrino4 & MA Hollywood. LINGO1 is a novel delta subunit that modulates large conductance, Ca2+ activated potassium channels. (NB: Not published) 40. R Dwivedi, RJ Large, E Bradley, G Litherland, MA Hollywood, GP Sergeant & KD Thornbury (2019). The effect of inhibiting TMEM16A on carbachol-induced contractions in murine primary bronchial smooth muscle. (NB: Not published) 41. RM Matthews, E Bradley, RJ Large, L McGarvey, GP Sergeant, MA Hollywood & KD Thornbury (2019) The role of voltage-gated sodium channels in murine airway smooth muscle. (NB: Not published) 42. 42. L Morgan, MA Hollywood, KD Thornbury, L McGarvey & GP Sergeant (2019) Role of large-conductance Ca2+ - activated K+ channels in PGE2-induced relaxations of murine airway smooth muscle. (NB: Not published) 43. Kulkarni S, Dudem S, Large RJ, Sergeant GP, Thornbury KD and Hollywood MA (2019) LINGO proteins - novel inactivating regulatory subunits of BK channels. (NB: Not published) 44. Woods, G Litherland, J Lockhart, A Hursthouse, F Lundy, G Sergeant and I McLellan. Metal ratio analysis of ambient particulate matter. June 2019. Meeting of Society for Environmental Geochemistry & Health. https://www2.mmu.ac.uk/media/mmuacuk/content/documents/faculty-ofscience-and-engineering/segh/Final_abstract_book_260619.pdf 45. K. Black, A. MacKenzie, L. Dunning, A. Crilly, J. Brzeszczynska, L. McGarvey, K. Thornbury, C.S. Goodyear, J.C. Lockhart, G.J. Litherland (2019). Proteinase activated receptor-2 (PAR2) modulation of murine lung and airway function. (Poster). (NB: Not published) 46. K McCallum, M Bailo, L Dunning, L McGarvey, M Hollywood, J Brzeszczynska, A Crilly, J Lockhart, G Litherland (2019). Proteinase activated receptor-2 induced autophagy dysregulation. (Oral). Thorax Suppl. (NB: In press) 47. M Bailo, L Dunning, J Brzeszczynska, K McIntosh, R Plevin, L Martin, G Sergeant, C Goodyear, G Litherland, J Lockhart, A Crilly (2019). Reduction of inflammatory cytokine production in chronic obstructive pulmonary disease (COPD) epithelial cells by protease activated receptor 2 (PAR2) antagonism. (Oral). Thorax Suppl. (NB: In press)
Published Scientific Papers	48. Bradley E, Large RJ, Bihun VV, Mullins ND, Sergeant GP, Hollywood MA, Thornbury KD. (2018) Inhibitory effects of openers of large-conductance Ca2+- activated K+ channels on agonist-induced phasic contractions in rabbit and mouse bronchial smooth muscle. Am J Physiol Cell Physiol. doi:10.1152/ajpcell.00068.2018. 49. Roe NA, Lundy FT, Litherland GJ, McGarvey LPA (2019). Therapeutic targets for the treatment of chronic cough. Curr Otorhinolaryngol Rep https://doi.org/10.1007/s40136-019-0239-9.