INTERREG VA IMPACT EVALUATION – FINAL REPORT

PRIORITY 1 – RESEARCH AND INNOVATION

Cogent Management Consulting LLP

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INTERREG VA IMPACT EVALUATION

PRIORITY 1 – RESEARCH AND INNOVATION

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Appendices

List of Abbreviations

Abbreviation	Definition
AAL	Ambient Assisted Living
AFBI	Agri-Food and Biosciences Institute
AFC	Authentic Food Company
AFRC	Advanced Forming Research Centre
AICBRN	All-Island Climate and Biodiversity Research Network
AKI	Acute kidney injury
ARCH	Applied Research for Connected Health Centre
AREA	Action Renewables Energy Association
BDI	Biomedical Diagnostics Institute
BETTA	British Electricity Trading Transmission Arrangements
BREATH	Border and Regions Airways Training Hub
BSR	Business Status Review
B2B	Business to Business
C-TRIC	Clinical Translational Research and Innovation Centre
CASE	Centre for Advanced Sustainable Energy
CB	Cross-border
CDHT	Centre for Digital Healthcare Technology
CEO	Chief Executive Officer
CIT	Cork Institute of Technology
CKD	Chronic Kidney Disease
CO	Output Indicators
Co2	Carbon dioxide
Co-Innovate	The Innovation Pathway Programme
COPD	Chronic Obstructive Pulmonary Disease
COVRES	COVID Response Study
CPM	Centre for Personalised Medicine: Clinical Decision Making and Patient Safety
CSRI	Computer Science Research Institute
CTRIC	Clinical Translational Research and Innovation Centre
DCSDC	Derry City and Strabane District Council
DCU	Dublin City University
DEMON	Deep Dementia Phenotyping Network
DfE	Department for the Economy
DIT	Department for International Trade
DJEI	Department of Jobs, Enterprise and Innovation
DKIT	Dundalk Institute of Technology
DNDI	Dementia and Neurodegeneration Ireland
EAPCI	European Association of Percutaneous Cardiovascular Interventions
EBR	East Border Region Ltd
ECG	Electrocardiogram
ECME	Eastern Corridor - Medical Engineering Centre
EIMR	Environmental Interactions of Marine Renewables
EMEC	European Marine Energy Centre:
EP	Enterprise Partners
ER	Eligible Region
ERDF	European Regional Development Fund
ESB	Electricity Supply Board
EU	European Union
EUBCE	European Biomass Conference and Exhibition
EV	Electric Vehicles
EWTEC	European Wave and Tidal Energy Conference
FCU	Financial Control Unit
FLC	First Level Control
FTEs	Full-Time Equivalent Employees
GSK	GlaxoSmithKline
HEI	Higher Education Institution
HIE	Highlands and Islands Enterprise

Abbreviation	Definition
HLS	Health and Life Sciences
HR	Human Resources
HSE	Health and Safety Executive
ICU	Intensive Care Unit
IEA	International Energy Agency
IP	Intellectual Property
IPR	Intellectual Property Rights
IRBEA	Irish BioEnergy Association
ISCE	The International Society for Computerised Electrocardiology
ISEM	Integrated Single Electricity Market
ISG	International Stakeholder Group
ITS	Institute of Technology Sligo
KE	Knowledge Exchange
KTP	Knowledge Transfer Partnership
LEA	Local Enterprise Agency
LEO	Local Enterprise Offices
LoO	Letter of Offer
LPE	Laser Prototypes Europe
LUH	Letterkenny University Hospital
LyIT	Letterkenny Institute of Technology
MEG	Magnetoencephalography
MEP	Member of European Parliament
MES	Mass Energy Storage
MNI	Manufacturing NI
NHS	National Health Service
NHSH	NHS Highlands
NI	Northern Ireland
NIACE	Northern Ireland Advanced Composites and Engineering Centre
NIBEC	Nanotechnology and Integrated Bio-Engineering Centre
NICE	National Institute for Health and Care Excellence
NICRS	Northern Ireland Clinical Research Services
NIHE	Northern Ireland Housing Executive
NIHR	Northern Ireland Multimorbidity and Research Discovery
NIREV	Northern Ireland Reforming the Vision
NREAP	National Renewable Energy Action Plan
NUIG	National Universities of Ireland Galway
NWCAM	North West Centre for Advanced Manufacturing
PCI	Primary Coronary Intervention
PDRA	Post-Doctoral Research Associate
PhD	Postgraduate Doctoral Degree
PI	Principal Investigator
POC	Point of Care
POCT	Point-of-Care Testing
PPE	Personal Protective Equipment
PV	Photovoltaic
QUB	Queen's University Belfast
R&D	Research & Development
R&D&I	Research, Development & Innovation
R&I	Research & Innovation
RA	Research Associates
Randox	Randox Laboratories Ltd
RCs	Research Clusters
RE	Renewable Energy
REF	Research Excellence Framework
ROI	Republic of Ireland
ROS	Reactive Oxygen Species
RTDI	Research, Technology Development and Innovation
RULET	Rural-Led Energy Transition

Abbreviation	Definition
SAMS	Scottish Association for Marine Science
SE	Scottish Enterprise
SEF	Strategic Energy Framework
SEM	Single Electricity Market
SEUPB	Special European Union Programmes Body
SMART	Specific, Measurable, Achievable, Realistic and Timebound
SMEs	Small and Medium-sized Enterprises
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
SSAD	Small-Scale Anaerobic Digester
ST	Southern Trust
STEM	Science, Technology, Engineering and Maths
STEMM	Science, Technology, Engineering, Maths and Medicine
SWC	South West College
TCD	Trinity College Dublin
TRL	Technology Readiness Level
UCC	University College Cork
UCD	University College Dublin
UHI	University of Highlands and Islands
UK	United Kingdom
UKRI	UK Research and Innovation
UoG	University of Glasgow
UoS	University of Strathclyde
UU	Ulster University
UWS	The University of the West of Scotland
VRE	Variable Renewable Energy
VRGS	Virtual Research Graduate School
WHO	World Health Organisation
WHSCT	Western Health and Social Care Trust
XR	Extended Reality

1. INTRODUCTION AND BACKGROUND

1.1 Introduction

The Special EU Programmes Body (SEUPB) has commissioned Cogent Management Consulting LLP (Cogent) to undertake a longitudinal Impact Evaluation of the INTERREG VA Programme (for Northern Ireland, Ireland and Western Scotland) Investment Priority Axis 1 – Research and Innovation to include three reports due by end of 2018, end of 2020 and early 2022.

This report represents the final in the series of three impact evaluation reports and provides an overview of the key activities and achievements of each project that was funded under Priority Axis 1. It also includes a summary of the previous evaluation findings and is anticipated to contribute directly to SEUPB's programme summary of evaluation findings, to be submitted to the EU Commission. A separate Executive Summary Document has also been prepared.

It is noted that as a consequence of the outworkings of the Covid-19 pandemic and resultant delays caused in the implementation of projects, only one of the eight individual projects supported under Priority Axis 1 had been fully completed at the time (circa April/May 2022) of the Evaluation Team's consultations to inform this report (see Table 1.5 for further details), albeit most projects were nearing completion. However, for SEUPB's reporting requirements to the EU Commission, it was necessary to develop the final evaluation report at this time, therefore the report does not reflect the final position of most of the projects.

This section of the report provides an overview of the Interreg VA Programme, Priority Axis 1 – Research and Innovation, its aims and objectives and the eight projects supported.

1.2 Background to the INTERREG VA Programme

Launched in January 2016, the INTERREG VA Programme was one of over sixty funding programmes across the EU that had 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.

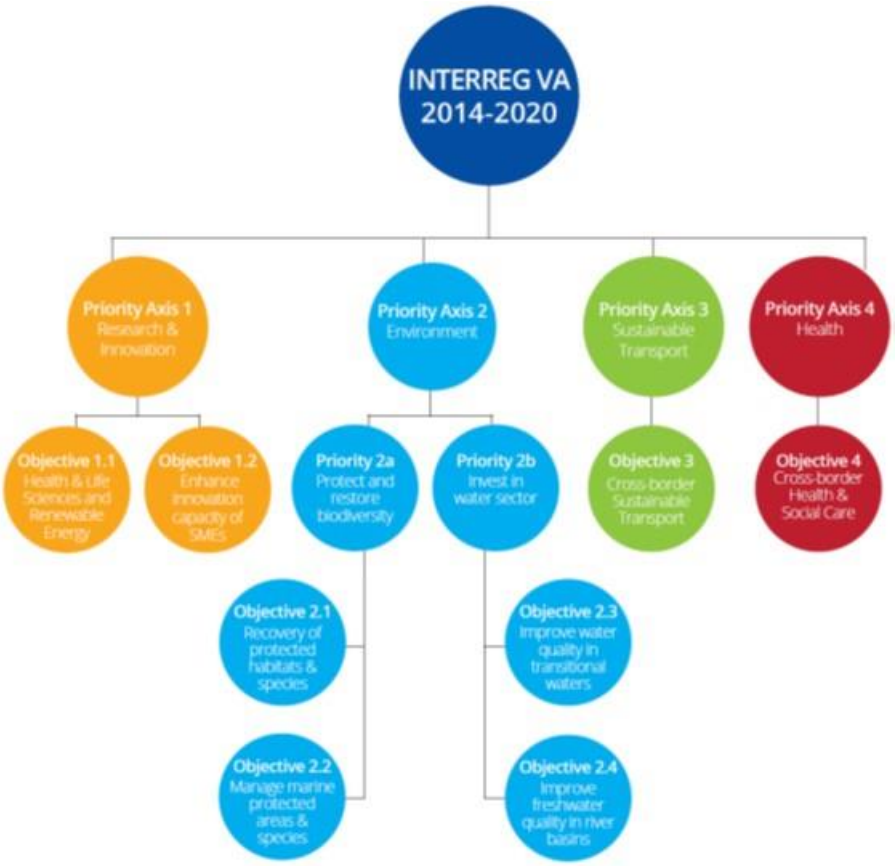
The INTERREG VA Programme, therefore, aimed to promote greater levels of economic, social and territorial cohesion to create a more prosperous and sustainable cross-border region.

The Programme had a total value of €283m, which was 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 have varied between priority axes of the Programme.

Figure 1.1: INTERREG VA Programme Priority Axes[1]



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 Co-operation Programme for the INTERREG VA Programme 2014-2020[2]. The Co-operation 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 Co-operation 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 – Rationale & Objectives

1.3.1 Introduction

The Co-operation Programme (CP) 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."*

[1] Source: Citizens' Summary: INTERREG VA Programme (2014-2020).
[2] Formally adopted in February 2015.

It was anticipated that this priority axis would 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).[3]

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 (HLS) 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.

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 Need for Investment

The Co-operation Programme outlined that the eligible region's economies are characterised by a low proportion of high-value-added exporting sectors and low levels of Research, Development and Innovation (R&D&I).

Noting that R&D&I had the potential to be 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 was anticipated that the INTERREG VA Programme would present 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).

[3] 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.

Aim of the Investment Priority & Specific Objective

The aim of this investment priority (and its Specific Objective) was 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 toward the development of a more competitive, high value-added economy[4].

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:

1. Health and Life Sciences (HLS); and
2. Renewable Energy.

It was anticipated that this focused approach would further develop research areas in which there was existing critical mass and where the region was considered to have distinct advantages (thereby aligning with the EU Smart Specialisation Platform).

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 Need for Investment

The Co-operation Programme identified a range of barriers that were contributing to a low level of innovation activity among SMEs in the eligible region including the cost of innovation, a lack of internal funds and a lack of external finance.[5]

Aim of the Investment Priority & Specific Objective

The aim of this investment priority (and its Specific Objective) was 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 sought 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.

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:

1. Preparatory interventions delivered via workshops;
2. Preparatory interventions delivered on a one-to-one basis;
3. An Innovation Capability Development Programme;
4. A cross-border Innovation Internship Programme; and
5. Cross-border R&I Projects.

[4] The term R&D encompasses three types of activities: basic research, industrial research and experimental development. However, only industrial research and experimental development activities were eligible for support under the INTERREG VA programme.
[5] The CP defined innovation as the development of solutions that meet needs in new ways. The CP considered innovation to be wider than R&D insofar as it also covered improvements to products, tradable services and processes.

1.3.4 Summary of Specific Objectives, Result Indicators and Targets

Table 1.2 provides a summary of the Specific Objectives, Result Indicators and Targets for Priority Axis 1: Research and Innovation:

Table 1.2: 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; HLS and Renewable Energy	The annual number of peer-reviewed journal and conference publications in two target sectors (HLS 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%

In January 2023, SEUPB advised the following concerning the Objective 1.1 result indicator:[6]

- **Project Targets:** Each of the seven projects supported has its target for publications, which is reflected in the project's Letter of Offer. This project (or LoO) target is an absolute number and may include inter-regional publications (depending on the wording of a given project's letter of offer). SEUPB notes that from a contractual point of view, these project-level targets are the only targets that projects need to concern themselves with.
- **Programme Target:** SEUPB advises that the programme-level target is envisaged to be measured with a three-year rolling average, with the final target for 2023 being an average of 75 publications with cross-border authorship and with the potential to create economic impact across the years 2021, 2022 and 2023 (per Table 1.3). SEUPB notes that projects should not be judged against this target, which only relates to the programme as a whole.

Table 1.3: Projected Result Indicator Target (Per Technologia's report)[7]							
	Health and life sciences			Renewable energies			Total Three-year average
Year	**Researchers**	**Publications**	**Three-year average**	**Researchers**	**Publications**	**Three-year average**	
2015	-	-	-	-	-	-	
2016	30	-	-	26	-	-	
2017	52	-	-	45	-	-	
2018	50	-	-	44	-	-	
2019	49	24	**8**	43	21	**7**	**15**
2020	47	43	**22**	41	37	**19**	**42**
2021	46	42	**36**	40	36	**31**	**68**
2022	-	40	**42**	-	35	**36**	**78**
2023	-	39	**40**	-	34	**35**	**75**

[6] Source: Email received from the SEUPB (Managing Authority) on 31st January 2023.
[7] Source: Final Report for priority axis 1: Research & Innovation (Technologia, August 2014)

The Output Indicators associated with Axis 1: Research and Innovation and its Specific Objectives are summarised below:

Table 1.4: Summary of Output Indicators

Output Indicator[8]	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 co-operating 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**

[8] Each output indicator is defined in the 'Output Indicator Guidance' documents for Objectives 1.1 and 1.2.

1.4 Overview of Projects and Partners

There were two calls for applications under Priority Axis 1: Research and Innovation. A two-stage process was then initiated by SEUPB's Joint Secretariat to assess applications submitted under each of the calls.[9] Full details of the assessment process, including admissibility criteria, were outlined for applicants in the 'Call Documentation' and the 'Guide for Applicants'.

In total, eight projects were approved by the IVA Programme Steering Committee.[10] As illustrated below, seven projects were funded under Specific Objective 1.1 of the R&I Priority Axis; whilst one project - the Co-Innovate Programme – was funded under Specific Objective 1.2.

Table 1.5: Summary of Projects Approved for Funding[11]

Lead Partner	Project Name	Operational start date	Original Anticipated end date	Latest (in July 2022) Revised Operational end date
Objective 1.1				
Dundalk Institute of Technology (DKIT)	BREATH (Border and Regions Airways Training Hub)	01/01/2017	31/12/2021	30/06/2022
Catalyst Inc.	NWCAM - North West Centre for Advanced Manufacturing	01/04/2017	31/12/2021	30/06/2022
Ulster University (UU)	ECME - Eastern Corridor - Medical Engineering Centre	01/03/2017	31/12/2021	31/07/2022
Ulster University (UU)	CPM - Centre for Personalised Medicine: Clinical Decision Making and Patient Safety	01/04/2017	31/12/2021	30/06/2022
South West College (SWC)	Renewable Engine	01/01/2017	31/07/2021	31/01/2022
Ulster University (UU)	SPIRE 2 - Storage Platform for the Integration of Renewable Energy 2	01/03/2017	31/12/2021	30/09/2022
Queen's University Belfast (QUB)	The Bryden Centre for Advanced Marine and Bio-Energy Research	01/06/2017	31/12/2021	30/06/2022
Subtotal				
Objective 1.2				
InterTradeIreland	Co-Innovate (The Innovation Pathway Programme)	01/08/2016	31/03/2022	31/03/2023
Total				

As reflected in Table 1.5, as a consequence, largely of the outworkings of the Covid-19 pandemic and its associated restrictions, each of the eight projects received extensions to their original anticipated end dates.[12]

[9] 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).
[10] Projects were approved at IVA Programme Steering Committees held on: 6/9/2016, 7/9/16, 23/11/2016 and 14/3/2017.
[11] Source (unless otherwise stated): Letters of Offer issued by the SEUPB.
[12] The most recent amendment is noted here, with further detail of previous extensions detailed in the respective project sections.

The seven projects that were funded under Specific Objective 1.1 received original Letters of Offer awarding cumulative ERDF and Government Match funding of c. €54.7m towards total project costs of €57.6m. The Co-Innovate Programme, which was funded under Specific Objective 1.2 received an original Letter of Offer awarding funding of c. €16.7m towards total anticipated project costs of €22.4m.

Table 1.6: Summary of Projects Approved for Funding[13]

		Per Original LoOs				Per Latest LoO (July 2022)			
Lead Partner	**Project Name**	**ERDF**	**Govt. Match**	**Other**	**Total**	**ERDF**	**Govt. Match**	**Other**	**Total**
Objective 1.1									
Dundalk Institute of Technology (DKIT)	BREATH (Border and Regions Airways Training Hub)	6,781,065	946,206	779,658	**8,506,929**	7,105,662	969,834	829,870	**8,905,366**
Catalyst Inc.	NWCAM - North West Centre for Advanced Manufacturing	7,462,875	1,055,531	261,447	**8,779,853**	7,462,875	1,050,425	266,553	**8,779,853**
Ulster University (UU)	ECME - Eastern Corridor - Medical Engineering Centre	7,108,480	1,043,238	211,199	**8,362,917**	7,108,480	1,043,238	211,199	**8,362,917**
Ulster University (UU)	CPM - Centre for Personalised Medicine: Clinical Decision Making and Patient Safety	7,415,033	1,213,953	795,941	**9,424,927**	7,415,033	1,213,953	795,941	**9,424,927**
South West College (SWC)	Renewable Engine	5,067,830	734,596	302,569	**6,104,995**	5,067,817	734,609	302,569	**6,104,995**
Ulster University (UU)	SPIRE 2 - Storage Platform for the Integration of Renewable Energy 2	5,668,754	794,174	240,318	**6,703,246**	5,668,754	794,174	240,318	**6,703,246**
Queen's University Belfast (QUB)	The Bryden Centre for Advanced Marine and Bio-Energy Research	8,289,778	1,077,624	385,278	**9,752,680**	8,289,778	1,075,706	387,196	**9,752,680**
Subtotal		**47,793,815**	**6,865,322**	**2,976,410**	**57,635,547**	**48,118,399**	**6,881,939**	**3,033,646**	**58,033,984**
Objective 1.2									
InterTradeIreland	Co-Innovate (The Innovation Pathway Programme)	14,702,502	1,969,242	5,771,291	**22,443,035**	13,949,530	1,934,276	4,823,379	**20,707,185**
Total		**62,496,317**	**8,834,564**	**8,747,701**	**80,078,582**	**62,067,929**	**8,816,215**	**7,857,025**	**78,741,169**

As illustrated above, as a consequence of project amendments, some projects received amended Letters of Offer, which led to the cumulative ERDF and Government Match grant awarded to Specific Objective 1.1 projects increasing from c€54.7m to €55.0m; whilst the ERDF and Government Match funding awarded to the Co-Innovate Programme decreased from c€16.7m to €15.9m. The rationale for changes in individual project budgets is discussed within the respective sections of this report that relate to individual projects (i.e. Sections 3 to 10).

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

1.5 Project Contributions

The contribution that each of the eight projects was anticipated to make to the Output Indicators is detailed below:

Table 1.7: Projects Approved for Funding – Stated Contributions to Output Indicators (source: Letters of Offer issued by the SEUPB)									
	1.1 – Life & Health Sciences				1.1 – Renewable Energy			1.2	
Output Indicator	**BREATH**	**NWCAM** [14]	**ECME**	**CPM**	**Renewable Engine**	**SPIRE2**	**Bryden Centre**	**Co-Innovate**	**Total**
No. of enterprises receiving support	5	9	10	5	8	12	30	1,408	**1,487**
No. of enterprises receiving grants	2	2	5	3	4	2	8	30	**56**
No. of enterprises receiving non-financial support	5	9	10	5	8	12	30	1,408	**1,487**
Years of PhD (or above) level research	89.5	98.5	95	80.19	57.0	83	132.5	n/a	**635.69**
No. of enterprises cooperating with research institutions	5	9	10	5	8	12	30	50	**129**
No. of enterprises participating in cross-border, transnational or inter-regional research projects	2	9	10	5	8	12	30	30	**106**
No. of research institutions participating in cross-border, transnational or inter-regional research projects	3	4	5	4	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**

[14] The targets for outputs CO01, CO04, CO26 and CO41 were revised in the 20th September 2021 LoO (from 8 to 9).

1.6 The Evaluation – SEUPB's Requirements & Methodology

1.6.1 SEUPB's Requirements

To fulfil the requirement of Article 114(1) of the Common Provisions Regulation (EU No: 1303/2013), SEUPB's Managing Authority submitted to the Commission an Evaluation Plan for the INTERREG VA Programme[15]. The Evaluation Plan was put in place to facilitate learning and maximise the proposed investments of the Programme[16]. The Plan outlined 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.

Concerning 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.

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 was being undertaken across INTERREG VA concurrently with the Impact Evaluation, **the Impact Evaluation was not expected to assess the implementation of projects nor how the Programme had operated. Rather than addressing financial and operational issues,** the purpose of the impact evaluation was learning, through an exploration of the contribution of the Programme to the movement of the Result Indicator, to inform the INTERREG VA Programme and potential future programming periods.

As such, the Impact Evaluation Team was required to assess the following:

- To what extent were the Specific Objectives achieved?
- To what extent were the targets for the Result Indicators achieved?
- Comment on the effectiveness and added value of cross-border collaboration concerning the Specific Objectives.
- Identify if any external factors impacted, positively or negatively, the achievement of the Specific Objectives.
- Comment on whether the two target sectors were appropriate.
- Identify whether there were synergies between projects funded under both objectives;

[15] 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.

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

- Whether collaborations had affected the quality and capacity for research and innovation in the eligible area?
- What had been the impact on business and industry?
- What had been the impact of cross-border collaborations under both objectives?
- Whether any new ways of working/partnerships/relationships had been created as a result of activities carried out within the priority axis?
- Identify any key areas of best practice and learning;
- Identify whether there were any barriers to cross-border Co-operation that the priority axis had not addressed.
- The contribution of the priority axis to[17]:
  - The EU Cohesion Policy and EU 2020 objectives;
  - The Atlantic Strategy; and
  - The horizontal principles of equality and sustainable development?

1.6.2 Methodology

Across the three distinct cycles of research, the Evaluation Team employed the following methodology:

- Consulted with SEUPB personnel both to identify report-specific requirements and to identify any project-specific issues encountered or developments of note;
- Extensive desk research activities that encompassed detailed reviews of materials such as:
- INTERREG VA policy and operational documents, such as the Co-operation Programme;
- Policy and strategy documents of specific relevance to individual projects and/or the eligible region;
- Project applications and supporting materials;
- Letters of Offers and subsequent amendments (where relevant);
- Analysis of all monitoring data available on the progress of projects supports including both activities undertaken and their financial expenditure against budget;
- Extensive engagement with the eight individual projects to assess the project against targets and key achievements.

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

2. THE POSITION BEFORE THE FINAL REPORT

2.1 Introduction

As reflected in Section 1, the specification for the evaluation requested that this final report provide a summary of the findings featured in the previous evaluation reports. At a high-level, the first two reports considered the following:

1. The first report considered the mobilisation of the eight projects and their early progress towards achieving their output indicators. This early activity also naturally led to a detailed consideration of the intervention logic associated with the priority axis;
2. Given the considerable upheaval caused to many aspects of organisations' operations and people's lives, the second report placed a particular emphasis on the impact of the pandemic on projects, emerging risks and barriers to the successful completion of projects, and the identification of methods by which such risks or barriers could be minimised.

This section provides a summary of the key findings featured in those reports.

2.2 The Mobilisation of Projects

At the time of the first report, each of the eight projects was, for the most part, at the early stages of its rollout, and whilst some had encountered some operational issues, none reported any issue pertaining to their mobilisation that they considered, at that time, to be significant enough to ultimately affect the successful delivery of their project. Albeit, even at that early juncture, some projects were of the view that delays encountered would likely mean that they would require an extension to the timeframes stipulated in their respective Letters of Offer.

The types of issues encountered included the following:

- **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 projects. A commonly shared view amongst the Partners was 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 arisen because several 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 Health and Life Sciences). This inadvertently created significant demand within the market for those students at the one time, resulting in a shortage of available students and, by association, delays in recruitment.

  On the supply side, it was noted by several partners that there had been limited appetite from domestic applicants which was suggested might have resulted from several factors including the scale of the research bursary that was available to potential students, 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 demand and supply side factors, several partners indicated that they had to ultimately seek applications from potential international PhD students.

- **Staff mobility issues** – Related to the above, difficulties had been encountered concerning non-EU resident PhD students taking up research positions in the eligible region due to visa-related restrictions. At the time of the first report, several the Projects' Partners expressed concern that such mobility issues might potentially be exacerbated following the UK's departure from the EU (i.e. following 'Brexit');

- **'Background' and 'foreground' IP issues impacting business recruitment and wider engagement in research projects** - Several of the projects' partners noted that they had faced difficulties encouraging business engagement on their respective projects due to concerns relating to IP. For some businesses, these concerns were 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 anticipated to be owned by the academic institutions;

- **EU/SEUPB and University procurement requirements hindering the progression of research** - Several the project partners considered that their project's progression 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)** - Some project partners indicated that there have been several changes to the profile of their project's research team during the initial delivery period which had, on occasions slowed project progress;

- **Changes to industrial partners** - A small number of project partners indicated that their originally anticipated industry partners had to be replaced due to a variety of business-specific circumstances (e.g. businesses going into administration, businesses having more pressing priorities); and

- **The claims process adversely impacted business engagement** - A small number of project partners noted that the administration and bureaucracy associated with the claims process had resulted in businesses leaving their project and other businesses not being willing to receive the financial support that was potentially available through the projects.

Nonetheless, at the time of the first report, each of the seven projects that had been funded under Specific Objective 1.1 was progressing with their PhD (or above) led research and the majority of the projects had identified the businesses that were anticipated to benefit from direct financial support to take forward additional R&I activity.

The final project (and the only project that had been supported under Specific Objective 1.2) had made strong progress concerning the delivery of the knowledge transfer and capability strands of the Programme (Strands 1, 2 and 3), but had at the time of the first report only begun to approve businesses/projects that were anticipated to receive financial support (through Strands 4 and 5). However, the Co-Innovate Programme project partners did (at the time of the first report) raise concerns that the outworkings of Brexit might affect their efforts to recruit businesses onto Strands 4 and 5 of their programme. This was because it was anticipated that businesses participating in Strands 4 and 5 would be required to contribute 50% of their project costs, and the project partners had received some indication from businesses that had participated in Strands 1, 2 and 3 that they had reservations concerning the commitment of funds and resources that might ultimately be required to address emerging needs following Brexit.

Other issues encountered at the time of the first report by the Co-Innovate Programme project partners included:

- **Delays in businesses progressing along the Co-Innovate support funnel due to Strand 2 'bottlenecks'**- The project partners advised that the requirement for businesses to complete two separate business assessment tools (i.e. a Business Status Review and Innovation Capability Audit) in Strand 2 had inadvertently served to delay the progress of businesses through to subsequent strands of the Programme's support;

- **Delivery of activity in the Highlands and Islands area of the eligible region** - Levels of activity in this area were below what was anticipated at the outset due to two interrelated reasons. Firstly, the project partners had not anticipated the time that would be required to engage with businesses located in these peripheral locations on a face-to-face basis. Secondly, and related to this point, the project partners had originally anticipated that activity in the Highlands and Islands area would be delivered by two in-house Programme managers (as opposed to availing of external resources, as was being utilised in the other programme areas). However, in retrospect, the Project Partners considered that they had underestimated the level of resource that was required to deliver the Programme within the stipulated timeframes. Consequently, the Project Partners sought and received approval from SEUPB to utilise external consultants to support the delivery of Strand 2 activity within the Highlands and Islands area; and

- **Cross-border/transnational focus of support limiting engagement from some businesses** - Whilst acknowledging the anticipated merits of the cross-border and transnational nature of the support, the project partners were 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 had created (perceived or actual) geographical/logistical difficulties for some businesses, resulting in them being unwilling to participate in the Programme, particularly when other support mechanisms were available in their home jurisdiction which did not require them to take forward collaboration outside their home jurisdiction.

Across all eight projects, there was agreement that the INTERREG VA funding had successfully enabled the Project Partners to draw together different but complimentary skills and knowledge (e.g. in different academic research areas) and in doing so, had provided a strong platform to strengthen the capacity and capability of the academic institutions to undertake collaborative R&I for the ultimate benefit of business and industry.

Early synergies had emerged (both in actuality or the potential of such was actively 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 were focused on the area of renewable energy.

However, a key finding, at this early juncture, related to the reasonableness of the targets and indicators established for the Priority Axis. Indeed, even at the (then) early stage in the various Specific Objective 1.1 projects' rollout many of the programme-level output indicators had already been achieved and in most cases, exceeded by some considerable margin. A notable exception was the number of Years of PhD (or above) level research untaken, which the Evaluation Team considered unsurprising, given the fact that the research elements of the projects were continuing to be undertaken, and many projects had encountered some delays in the recruitment of research staff.

Consequently, the Evaluation Team noted the following observations:

- Whilst noting that the Common Output and Results Indicators had 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 appeared to be more overly representative of the 'activities' and 'inputs' being delivered under the Priority Axis, whilst the Results Indicator identified under Specific Objective 1.1 appeared to be more overtly representative of an 'Output'.

  The Evaluation Team noted that best practices in the UK concerning programme development and its evaluation (reflected, at that time, in guidance featured in the Northern Ireland Guide to Expenditure Appraisal and Evaluation and the UK Treasury's Green Book) identified the importance of establishing activity-based targets, it also advised that 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). The Evaluation Team subsequently advised that caution should be taken in utilising the stated output targets that had been established for the Investment Priority as an indicator of whether the Priority Axis had ultimately delivered value for money.

- On review of the number and nature of Common Output indicators, the Evaluation Team was of the view that fewer (or different) specific targets/indicators should have been adopted as (for those established) the delivery of a single element of activity offered 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 had been delivered under the Investment Priority.

The Evaluation Team also identified the following uncertainties concerning the Investment Priority's Result Indicators:

- The overall Results Indicator for Specific Objective 1.1 was stated as being to increase the annual number of peer-reviewed journal and conference publications in two target sectors (HLS and Renewable Energy) with cross-border authorship and with the potential to create economic impact from 4 to 75 by 2023. Concerning this, the Evaluation Team noted the following:
  - Based on the INTERREG VA Operational Programme, it was understood that the Managing Authority had carried out a survey interview of higher education institutions in the region to establish the number of peer-reviewed journals and conference publications within either of the two target sectors (HLS and Renewable Energy) that also had cross-border authorship to establish the annual baseline (which was subsequently identified as 4). However, based on the outputs from their research activity, several 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.
  - The Evaluation Team noted that given that it would appear more probable that the number of peer-reviewed journal and conference publications would likely ramp up in line with the levels of research activity being undertaken (and not, therefore, be linear over the life of a project), it would have been beneficial for annual quantified targets to have been established to ensure that progress could be measured at different junctures towards the (seeming) 2023 average annual target. Albeit, the Evaluation Team recognises that given delays in projects commencing due to difficulties securing PhD students and wider research staff that any annual targets established before the programme launch may have required subsequent revision as the programme and individual projects progressed.
  - Based on the Evaluation Team's discussion with Project Promoters, and its review of SEUPB's LoOs and Project Assessment materials and completed monitoring materials, the Evaluation Team identified that ambiguity existed as to the specific nature of the Result Indicator. Whilst noting that the Result indicator indicated that the quantified target relates to the annual number of peer-reviewed journals and conference publications, the review of SEUPB's Stage 1 and 2 Assessment reports for individual projects appeared to indicate that this target was, in many cases, being interpreted in terms of cumulative rather annual outputs.
  - The Evaluation Team noted that it was unclear as to how a publication's 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 was overtly focused on increasing business and industry-relevant research and innovation capacity.

- The Evaluation Team noted that the UK Treasury's Green Book guidance identifies 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 had been established, the Evaluation Team noted that it had reservations as to whether Priority Axis 1 had the potential to fully deliver on this indicator of value-for-money, with the Evaluation Team advising that in its view (but based upon its experience of evaluating many other similarly focused interventions available within the eligible region such as Invest NI's Competence Centre Programme, Grant for R&D Programme etc.) many of the output indicator targets had been set at too low a level.

NB: The Evaluation Team was subsequently commissioned to analyse what would be more appropriate targets. SEUPB has advised that these revised targets will form the basis of a programme modification to increase the target values.

2.3 The Impact of the Pandemic on Projects (in December 2020)

Given the considerable upheaval caused to many aspects of organisations' operations and people's lives, the second report placed a particular emphasis on the impact of the pandemic on projects, emerging risks and barriers to the successful completion of projects, and the identification of methods by which such risks or barriers could be minimised.

The key findings from the Evaluation Team's consultation with project partners at the time (December 2020) of the second report included:

- 6 of the 8 projects considered that the onset of the COVID-19 pandemic and the associated lockdown and disruption to normal working practices had created a risk that their project would not fully achieve its aims and objectives. One project (NWCAM) considered that there was a 'high risk' that this was the case;
- 3 of the 8 projects had made some adaptations to their project as a result of the COVID-19 pandemic;
- 3 of the 8 projects considered that their project would likely require an extension to its originally anticipated timescales to complete successfully; and
- 1 of the 8 projects considered that they would likely not be able to spend their full budget allocation.

It should be noted that the Evaluation Team spoke with the projects at a time (end of August/start of September) when COVID-19 restrictions had been eased/lifted to some extent and projects may have been more optimistic about their ability to achieve project aims and objectives within the original timeframe. However, at the time of drafting the second report (late December 2020), further restrictions were being implemented in Northern Ireland and the Republic of Ireland, which the Evaluation Team noted might pose a significant risk to cross-border collaboration activities during their implementation.

Of further note, whilst six projects felt (in August/September 2020) it was feasible to make up for the delays experienced as a result of the pandemic, they noted that this would depend on how long the lockdown continued, as although the projects were considered to have adapted well to remote working, some work could not be completed remotely (e.g. laboratory-based work). It is the view of the Evaluation Team, at that time, that the ongoing uncertainty associated with the duration of lockdowns and the severity of restrictions, meant that there continued to be a significant ongoing risk to the successful completion of the projects.

Given the uncertainty, the Evaluation Team recommended that SEUPB continued (as it has been doing throughout the pandemic) to regularly monitor the activity undertaken and progress made by each project. In particular, the Evaluation noted that it would be important to engage with projects to discuss potential changes to project activities, timelines or budgets.

It is understood that SEUPB's Joint Secretariat subsequently asked each of the projects to formally report back in early 2021 as to any further project amendments that might be required as a consequence of the pandemic. A further point to note concerning this is that the Joint Secretariat advised that the Irish Government had offered to cover the cost of any extensions offered to PhD students to allow them to complete their studies.

The remainder of this report relates to the position of projects at the time of consultation concerning the development of this final evaluation report i.e. the period April to June 2022.

3. BREATH - BORDER AND REGIONS AIRWAYS TRAINING HUB

3.1 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.

3.2 Project Overview

3.2.1 Rationale for the Project

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[18]. It is highly prevalent in the border regions of Ireland and Western Scotland, with it suggested that COPD would be responsible for one-third of deaths by 2020.

COPD has also been associated with inequality and social deprivation as evidenced by the fact that there was a 200% difference in Irish COPD death rates between the lowest and highest occupational groups[19]. The INTERREG VA Eligible Region had been identified as an area of social deprivation that suffered 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, bore the unfortunate distinction of being amongst the world's leading countries in terms of its prevalence. For example, Ireland ranked 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 was amongst the highest in the UK, with notable 'hot spots' also occurring throughout NI, particularly in Belfast, Derry/Londonderry and the border areas of Fermanagh, Tyrone and Armagh.

COPD has also imposed a huge economic burden on the Region, not only on health services but also in terms of its wider economic impact. A report[20] 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, 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".

[18] Source: An Outcomes Strategy for COPD and Asthma, Companion Document NHS.
[19] National Respiratory (COPD) Framework 2008
[20] Chronic Obstructive Pulmonary Disease (COPD), Royal College of Physicians of Ireland, 2014

Similarly, in Scotland, COPD had been identified as being the only major cause of death on the increase. At the time that the project sought funding, there were thought to be about 100,000 people in Scotland living with COPD, with a predicted increase of 33% in the following 20 years. It accounted for over 122,000 bed days and 4,500 deaths every year. Audit Scotland estimated that the direct cost of COPD to NHS Scotland was £100m per year.

COPD was therefore under-recognised and undertreated; hence it was considered that there was a real need for impact in terms of prevention, treatment and management.

The need for the project was further 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 had been almost no research or training provision in this field. They suggested that this was 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 following 4 distinct areas of need were identified:

1. Within the region, there was high COPD incidence and great attendant social and economic costs.
2. The economies of the Region had a low proportion of high-value sectors and low levels of R&I.
3. There was no effective cross-border partnership that significantly impacted the overall regional capacity for R&I in Health and Life Sciences.
4. Although research capacity existed within the region, a lack of collaboration across the 3 jurisdictions had prevented the creation of critical mass necessary to achieve stronger market performance and a stronger innovation pipeline.

The BREATH project consequently focused its research on COPD both to directly address the first area of need identified, and also to serve as a vehicle for delivering solutions to the other specific needs identified.

3.2.2 Project Partners

The BREATH (**B**order and **RE**gions **A**irways **T**raining **H**ub) project was an ambitious, collaborative research Partnership that sought to harness the complementary resources and expertise of 10 Principal Investigators (PIs) from Dundalk Institute of Technology (DkIT), Queen's University Belfast (QUB) and the University of the West of Scotland (UWS).

3.2.3 Project Overview, Objectives and Activities

The project combined the project partners' expertise in airway smooth muscle (DkIT), epithelial and neuronal function (QUB) and inflammation (UWS) which was considered to be required to develop novel early diagnostic tests and treatments for COPD. QUB clinicians ensured that BREATH research was patient-focused. The project partners consider that the strength of BREATH was its drawing together of cross-regional expertise in airway cell biology, biomarker discovery and inflammation providing a hitherto unavailable opportunity to develop innovative new skills and models related to COPD.

The mission of the BREATH project was *"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 sought to develop an innovative, industry-relevant training programme to stimulate R&I, attract inward investment and enhance economic development in the Region.

The BREATH project's Letter of Offer identified the project's objectives as being to achieve the following:

1. To identify novel diagnostics and therapeutic targets to treat COPD;
2. To increase Research and Innovation across the Region by providing world-class training to the next generation of researchers;
3. To develop an innovative cross-border, interregional research hub focused on the unmet need of COPD;
4. To achieve a critical mass that will impact the Region by combining the partnership's complementary clinical, scientific, innovative and industrial skills.

To achieve their project objectives, the project partners advised that they would undertake the following activities.

- Engage with (at a minimum) 5 enterprises, through the provision of expert advice and support.
- Provide two (at a minimum) of the five enterprises with financial support. These businesses were to partner with BREATH and contribute to work packages for which they would receive financial support (a total of €250,000 over the 5 years, De minimus and State Aid rules applying).
- The remaining enterprises were to 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. Of note, the BREATH project further expanded the platform beyond the original 22 (6 PDRFs/Clin Fellow and 16 PhD students) to 28, including 3 match-funded PhD students and 3 additional PDRF/RAs.

To deliver the project activities, four work plans were developed, as follows:

Table 3.1: Summary of BREATH Project Work Plans (Per Progress Reports)
1. Management (management)
2. Scientific Research Projects
3. Technology Transfer Activities
4. Communication.

3.2.4 Anticipated Outcomes and Results

The project partners indicated that the infrastructure and expertise needed for excellent research training already existed within the partnership. However, BREATH aimed to upscale this to create a world-class training network to **maximise the career prospects and employability** of researchers in line with the Charter and Code for Researchers. To this end, the project partners utilised 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 was conducted on a cross-border and interregional basis.

Each of the BREATH PhD projects was run on a cross-border or interregional basis, which was anticipated to enhance the overall Regional capacity for R&I. The impact was to be quantified by the number of:

- Researchers trained by 2023;
- Industry engagements by 2023; and
- Collaborative publications by 2023 - It was anticipated that the BREATH project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 33 peer-reviewed publications (Open Access Green level as a minimum) with cross-border authorship. In addition, a further 15 peer-reviewed publications with interregional authorship.

3.3 Project Expenditure to July 2022

The BREATH project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €7,734,797 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,515,073. However, this was later amended (LoO dated 21st June 2017)[21] offering a grant of up to a maximum of €7,727,271 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,506,929.

In March 2020, BREATH requested additional INTERREG VA funding to complete the clinical testing activity of the project (utilising human samples), which was approved by the Programme Steering Committee on 27th January 2021. Subsequently, the SEUPB issued a revised LoO (dated 15th April 2021) offering a grant of up to a maximum of €8,075,496 (ERDF + Government Match Funding) to be expended and claimed towards total anticipated project costs of €8,905,366 by 30th June 2022, which in addition to granting a 6-month project extension and an increase in the overall budget also saw a reallocation of the budget between categories. The partnership requested additional INTERREG VA funding to complete the clinical testing activity of the project as QUB and UWS experienced several factors which increased costs for their clinical activity.

Further to the above, the Evaluation Team's review of SEUPB's EMS indicates that there has since been a further reallocation of the budget between categories, as reflected below. As of July 2022, the project reported a total actual expenditure of €8,131,646 equivalent to 91% of the total project budget, however, whilst the project was considered to have been completed at the end of June 2022, this may not reflect the final expenditure position due to the timing of submission and verification of final claims.

Table 3.2: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Total Actual Expenditure[22]	% of the total budget
Staff Costs	3,189,784	3,025,304	95%
Office and Administration Costs	1,755,030	1,610,669	92%
Travel and Accommodation Costs	100,324	75,546	75%
External Expertise and Services	3,342,397	2,948,485	88%
Equipment Costs	517,831	471,643	91%
Total	**8,905,366**	**8,131,646**	**91%**

Discussion with the BREATH project partnership in April/May 2022 indicated that they anticipate a small level of underspend due to unspent travel funds and funding for industrial collaborations.

[21] Following identification of an error in the figures approved for the office and administration budget.
[22] Source: SEUPB's EMS 18th July 2022

3.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the BREATH project's key achievements and the extent to which the 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, the project's ability to contribute to the achievement of the Specific Objective.

3.4.1 Key Activities Undertaken (to March 2022)

The Evaluation Team's review of the BREATH project partners' progress reports indicates that key activities undertaken since the second evaluation report (between July 2019 and March 2022) included the following:[23]

Table 3.3: Key Activities

Period	Dates	Key Activities /Points of Note
11	1st July 2019 - 30th September 2019	• Five cross-border authored conference presentations were delivered at the Federation of American Societies for Experimental Biology (FASEB) Conference. • Further cross-border authored presentations were delivered at both the 2019 International Kv7 Conference and Physiology 2019. • BREATH seminar speakers delivered lectures in DkIT. • A manuscript with cross-border authorship was submitted to the Proceedings of the National Academy of Sciences (PNAS) Journal for peer review.
12	1ST Oct 2019 - 31st December 2019	• Three PhD students submitted their PhD transfer reports. • Representatives from Almac and a QUB professor delivered a lecture to BREATH staff and students titled "Biomarkers for precision cancer medicine". • An outreach engagement programme was delivered to Adree National School in honour of science week. • The BREATH project was shortlisted for the QUB Vice-Chancellor's Research Culture Prize, and a video was produced for the awards ceremony. • DkIT Principal Investigators (PIs) and 5 PhD students presented their research by oral and poster communication at the Irish Thoracic Society (ITS) meeting in Galway. • Eight cross-border authored abstracts were presented at the Institute of Technology Sligo (ITS) and were accepted for publication in the Irish Journal of Medical Science.
13	1st January 2020 - 31st March 2020	• BREATH participated and had a stand at the NI Science Festival. • A PhD student received 1st prize for oral presentation at the 3rd year PhD Research Symposium. • A paper with cross-border authorship was published in the British Journal of Pharmacology in March. • A further cross-border and interregional paper was published in PNAS in January with extensive uptake by the national press. • Four cross-border authored abstracts were submitted to the European Respiratory Society International Congress in Vienna in September. • A further cross-border authored abstract was delivered at the European Thoracic Society Lung Science Conference in Estoril, Portugal.

[23] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time (July 2022) of writing. However, the most recently available collated Project Progress report was for period 20 (October – December 2021), albeit it was in progress and did not detail key activities or achievements. Therefore, key activities from this period onwards have been drawn from individual partner progress reports.

Table 3.3: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
14	1st April 2020 - 30th June 2020	• A Home Schooling Challenge was created and posted on the BREATH website to provide continued school support in the face of lockdowns as a result of Covid-19. • The BREATH annual conference was hosted by the University of West Scotland (UWS) via Zoom. • Furthermore, a letter with cross-border authorship was submitted to the Editor of The Journal of Allergy and Clinical Immunology; • Almac Discovery was approved as a BREATH industry partner in June.
15	1st July 2020 – 30th September 2020	• Informal progress monitoring of all 6 DkIT PhD students was completed virtually in September. • An article on the BREATH Project was published by Medcom on NIHealthcare.com in July. • Papers with cross-border authorship were submitted to Science Signalling and Critical Reviews in Microbiology in September.
16	1st October 2020 – 31st December 2020	• A paper with cross-border authorship was published in the European Respiratory Journal in October. • In addition, a paper with cross-border authorship was submitted in November to the American Journal of Respiratory Cell and Molecular Biology. • A book chapter by BREATH authors was accepted in the Handbook of Experimental Physiology in December. • The BREATH project was awarded the QUB Vice Chancellor's Award for Excellence in Research Culture in December.
17	1st January 2021 – 31st March 2021	• PhD Students and Post-Doctoral Research Fellows (PDRFs) continued to make progress with their experimental work in laboratories on a part-time basis (due to Covid-19 restrictions). • A paper with cross-border authorship was published in Critical Reviews in Microbiology in January. • Advanced discussions relating to the BREATH industry partnership took place with the CEO of Causeway Sensors. • Discussions continued with Axis Bioservices and pHion about Industry Partnerships. • The project was awarded additional funding of €348,225 in January from SEUPB for processing clinical samples.
18	1st April 2021 30th June 2021	• The BREATH 2021 virtual conference hosted by DkIT took place in June, with all BREATH and match-funded PhD students presenting their research. • BREATH industry training attended by representatives from Almac Discovery, Causeway Sensors, Axisbioservices and Almac Group was held virtually in June. • Two papers with cross-border authorship were published in the International Journal of Molecular Sciences. • A PhD student contributed to an article in 'Your EU' and presented their research and a published abstract at the British Association for Lung Research. • A partnership agreement was signed with Causeway Sensors.
19	1st July 2021 – 30th September 2021	• Four PhD students submitted their theses. • A co-authored paper was published by PNAS in September. • A partnership agreement was drafted for pHion. • SEUPB agreed for discussions to proceed with OmniSpirant as a potential new industrial partner.
20	1st October 2021 – 31st December 2021 (From Partner Progress Reports)	• Three PhD Students at DkIT successfully defended their PhDs in this quarter. • One student submitted their thesis. • A paper with cross-border authorship was accepted for publication in the Function Journal. • A further paper was published online in the British Journal of Pharmacology. • The BREATH mission to combat chronic obstructive pulmonary disease (COPD) in Dumfries & Galloway was highlighted in local newspapers including The Dumfries & Galloway News and the Galloway Gazette. The articles mentioned the possibility of developing a Centre of Excellence on Lung Health/COPD. Furthermore, the mission to combat COPD was

Table 3.3: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
		highlighted at several points in the Scottish Parliament debate to mark World COPD day.
21	1st January 2022 – 31st March 2022 (From Partner Progress Reports)	• Two PhD Students at DkIT successfully defended their PhDs. • The BREATH Dissemination Event was held on March 30th in Dundalk. • BREATH Clinical Affiliates and key colleagues delivered seminar presentations on lung reduction volume surgery to the BREATH team. • University of West Scotland research assistants and PhD students undertook a one-day placement in QUB laboratories to transfer protocols, skills and expertise to the UWS campus. • Two cross-border papers were published/accepted.

3.4.2 External Impact Factors

Discussion with the BREATH Project Partners indicates that the project encountered several issues during its delivery, which in combination served to slow progress towards the achievement of its output indicator targets. However, encouragingly, none of the issues encountered ultimately had a substantive adverse impact on their overall achievement. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the BREATH Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Project staff worked remotely during the lockdown, but no project staff were furloughed;
- Access to laboratories was not possible during the period of lockdown (a period of circa 5-6 months), followed by 12 months of half-time access, albeit students took the time during lockdown to write up and analyse what they had completed so far for their theses;
- Linked to the above, some reagents that expired during the time that the laboratories were inaccessible were lost (i.e. not usable).
- Initially, due to changeovers in staff and staff beginning to work remotely, the project experienced a few delays in accessing documentation relating to project expenditure. These problems were resolved as quickly as possible to allow staff to work through the claims process as best as possible to ensure the timely submission of claims.
- As travel was restricted, expenditure associated with the travel budget had been affected.
- A total of four face-to-face BREATH conferences were originally planned, however, two of these took place in a virtual format and the chance to have a face-to-face conference in Scotland was missed.
- Several online webinars and clinical seminars were organised, which were well attended.
- The project continued to cover all of what it set out to do, with 16 BREATH PhDs and 3 matched BREATH PhDs presenting their work at PDRF-chaired seminars. Additionally, TEVA provided an all-day training session as part of the online conference.
- The number of secondments of the students to Partner laboratories had to be reduced given the restrictions in place.
- The clinical network for patient sample collection was heavily impacted and delayed by COVID restrictions.
- DkIT and QUB had plans to work on human ex-vivo lung samples supplied to QUB, but the source of these dried up completely during COVID restrictions.

Ultimately, as outlined in Section 3.3, to allow the BREATH project further scope and time to progress its planned activities, the project received a six-month extension to the project to 30th June 2022.

During discussions in April/May 2022, the project partnership outlined that notwithstanding that the PhD students lost time in the laboratory resulting in some of the PhD submissions being delayed, as of

April 2022 only 3 of the 16 (BREATH-funded) students had yet to submit and the majority of those who had submitted had already successfully defended their PhDs. In the project partnership's view, the reason why COVID-19 had less impact in this regard than was imagined was that the students were already quite experienced when the pandemic struck, therefore they were able to use their time efficiently.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit did not affect the project to any great extent as it was already well established.

Whilst Brexit did not have a substantive impact on the BREATH project, the partnership noted their concerns that its outworkings had the potential to impact the likelihood of funding being available for similar cross-border projects in the future, and its potential to restrict the movement of researchers across-borders.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the BREATH project included:

- **The procurement and claims processes adversely impacting on businesses' engagement** – According to the Project Partnership, the levels of administration associated with the programme's procurement and claims processes resulted in one business that was originally anticipated to participate leaving the project and other businesses not willing to receive the available financial support;

- **Staff mobility issues** - Difficulties were encountered concerning the mobility of overseas students travelling outside their 'country of research residence'. That is, where for example, an overseas student's visa allowed them to conduct research in the Republic of Ireland, the project encountered complications if an aspect of their research meant that they would need to be in Northern Ireland;

- **Recruitment issues** - QUB 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 several reasons, not least the pressures that were 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 was amended from that anticipated at the outset the total quantum of research staff had increased.

  However, in hindsight, QUB suggested 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 the 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. This foresight allowed the University of the West of Scotland to receive clinical samples from hospitals within their region and in doing so enabled additional engagement with their local NHS and offered the opportunity for COPD patients in the eligible region to be involved in the clinical aspects of the BREATH project.

The project partnership outlined that apart from the COVID restrictions, there were no further significant negative factors which impacted the project's ability to achieve its aims and objectives. The project partnership highlighted the main positive factors for the project had been the successful recruitment of capable staff and students, and the spirit of collegiality established amongst the PIs.

3.4.3 Variation to Planned Activities

Discussion with the project partnership indicates that a small number of activities were not implemented in the way or extent that had been originally proposed as a result of the delays and restrictions caused by the Covid-19 pandemic including:

- Project delivery moved online. For example, the anticipated extensive Schools Outreach element of the project that was to be carried out by the PhD students within primary schools was revised into a form for use as a home-schooling exercise.
- Whilst it was anticipated that every student would spend time on secondment in Partner laboratories only a small number (4) of secondments were able to take place due to the COVID restrictions, as follows:

  - A DkIT Student was on secondment with QUB;
  - A QUB Student was on secondment with DkIT
  - A UWS Student was on secondment with DkIT and also completed a placement in a non-BREATH collaborative laboratory (University of Leicester).
  - A UWS Student was on secondment with QUB.

  However, all students had the opportunity to attend a 2-day bio tour of GSK Global Headquarters in Brentford and research facilities in Stevenage.

3.4.4 *Progress towards the Project's Output Indicators*

As of April 2022, the BREATH Project Partnership was of the view that it had fully achieved its anticipated (approved) project outputs, with:

- 7 enterprises receiving support (CO01) and non-financial support (CO04), and cooperating with research institutions (CO26);
- 3 enterprises receiving grants (CO02) and participating in cross-border, transnational or interregional research projects (CO41) (against the project's original target of 2);
- 93.6 research years (against the project's original target of 89.5); and
- 3 research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 3.4: Extent of Achievement of Project Output Indicator Targets

Output Code	Description	Programme Target	BREATH target	Achieved (as of April 2022)[24]	Variance against project target
CO01	Number of enterprises receiving support.	20	5	7	+40%
CO02	Number of enterprises receiving grants	10	2	3	+50%
CO04	Number of enterprises receiving non-financial support	20	5	7[25]	+40%
CO24	Number of new researchers in supported entities	514	89.5	93.6 (excluding UWS match-funded PhDs)	+5%
CO26	Number of enterprises cooperating with research institutions	10	5	7	+40%
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects	10	2	3	+50%
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects.	5	3	3	-

[24] Source: Discussion with Project Partnership.
[25] Examples include Intellectual input, knowledge exchange and technology transfer.

3.4.5 Key Achievements (to April 2022)

Discussion with the project partners indicates that they consider the following to be amongst the BREATH project's key achievements (as of April 2022):

- BREATH's mission was *"to establish a cross-border research hub for the development of innovative approaches to tackle COPD by identifying new targets and treatments".* The project partnership established a research and training hub between the 3 Partners in DkIT, QUB and UWS consisting initially of 10 Principal investigators and the cohort of PhD students and PDRFs (28 young scientists or 31 counting match-funded postgraduates in UWS). This network expanded to include BREATH Affiliates and Clinical Affiliates, numbering a further 16 academics and clinicians. The project has identified several potential targets for treatment, some of which have received press coverage.
- The project trained 28 scientists (including PhDs and PDRAs) (or 31 counting the 3 match-funded postgraduates in UWS).
- The project partnership noted that each PhD project was co-supervised across the Partnership. In addition, all PhD students participated in the annual BREATH conferences and expertise from partner laboratories had been used to expand the scope of individual PhD projects, examples include:

  - QUB Student learning the confocal Ca2+ imaging technique in DkIT,
  - DkIT Student availed of immunohistochemistry expertise in QUB,
  - DkIT Student availed of expertise in PAR2 receptors in UWS for a section of her thesis,
  - UWS Student learned myography in the DkIT.

  The project partnership highlighted that PhD students also co-wrote papers and conference presentations, for example, the 2018 Irish Thoracic Society meeting in Belfast was attended by the majority of the students, where they presented their collaborative research work. PhD students in Partner labs used compounds synthesised by the Medicinal Chemist PDRF in the DkIT Medicinal Chemistry Laboratory.

- In terms of the PhD students' progress (including the 3 UW students match funded), the project outlined the following (as of April 2022):

  - 6 PhDs were awarded;
  - 7 further were submitted;
  - 5 were nearly ready for submission (and on schedule following the Covid-related extensions received); and
  - 1 was behind schedule.

- Of the 19 supported PhD students, 17 are in employment, either in academia (7) or industry (10). In addition, the project partnership outlined that the majority (6 of 9) of PDRAs involved in the project were still employed in academia.
- In terms of the impact on students/academics, those involved in the BREATH project received a variety of awards, an overview of which is provided in Appendix III.
- The project has identified several new potential treatment targets for COPD.
- There have been 5 new invention disclosures.
- The project raised awareness of COPD through an extensive public engagement programme, including PhDs visiting primary schools. In addition, in August 2020, a QUB PhD Student had the opportunity to be interviewed for the BBC Northern Ireland TV series, 'Croí Uladh le John Toal.' This interview allowed BREATH to engage with a national audience, offer an overview of COPD and help highlight the importance of research in the development of our understanding of the disease.
- Linked to the above, with the upsurge in home-schooling due to COVID-19, the BREATH team revised the formal class BREATH Challenge into a form for use as a home-schooling exercise. While originally intended as a classroom exercise, children (and parents) were invited to

individually download and engage in the various challenges. Successful completion of all the challenges resulted in an award of a 'Certificate of Success'.

- The project partnership (as of April 2022) has active collaborations with 6 businesses in Ireland and the UK, 3 of which received funding from BREATH. A BREATH QUB PhD was appointed as a project leader with another of the business partners (who did not receive financial support), Axis Bioservices, who have set up a respiratory testing facility as a result of their collaboration with BREATH. Furthermore, the project has an ongoing collaboration with Biogen in the USA.

The project partnership also outlined the following new ways of working/partnerships/relationships that were created as a result of activities carried out within the project:

- A PDRF-led seminar series was set up during the periods of 'lockdown' to transfer knowledge and technical expertise across partners.
- The extensive Schools Outreach of the programme was carried out largely by the PhD students who visited primary schools and engaged pupils in activities that raised their awareness of COPD.
- Staff organised original links with the relevant council and teaching staff, resulting in invitations to engage and present at various Teacher training events, and to present to schools to meet immediate needs identified by the schools (e.g. vaping in or around school grounds).
- The idea of BREATH placing a fully funded researcher within the labs of Industrial Partners was novel and rewarding. This culminated in a successful application by BREATH Senior PDRF to UKRI for an Innovation Scholar Award which has since allowed his secondment to Almac Discovery.
- Patients were actively engaged in the programme, and this included having them engage and present at school visits, and also at the recent BREATH Dissemination meeting. Patients also featured and contributed to the BREATH webpage, including an article providing a patient's perspective.

3.4.6 *Progress toward the Project's stated Objectives*

Table 3.5 provides a summary of the progress that has been made by the project against its stated objectives.

Table 3.5: Project-Specific Objectives[26]

Project Specific Objectives	Level of Achievement	Explanations
To identify novel diagnostics and therapeutic targets to treat COPD.	To a large degree	As of September 2021, the PhD students were continuing to progress their projects combining laboratory work and the writing of thesis chapters. As noted, during discussion in April 2022, the project partnership further advised that • The project identified several new potential treatment targets for COPD. • There had been 5 new invention disclosures.
To increase research and innovation across the region by providing world-class training to the next generation of researchers.	To a large degree	As of September 2021, the BREATH training programme continued to review opportunities for industry-led training. BREATH industry partners, TEVA, GSK and Chiesi had made a substantive contribution to date to the personal and career development of the students. New links with industry continued to be established which included Almac Diagnostic, Causeway Sensors, pHion and Axis Bioservices all of which contributed to the delivery of an industry-led training day as part of the BREATH2021 conference. Several students had taken the opportunity to be involved in undergraduate teaching which they used in applications to be recognised as an Associate Fellow of the Higher Education Academy (AHEA).
To develop an innovative cross-border, interregional research hub focused on the unmet need of COPD.	To a large degree	As of September 2021, the BREATH project continued to strengthen collaborative links across research interests and opportunities for public and industry engagement as evidenced by collaborative working and papers. A new industry contact was OmniSpirant, a County Tipperary-based company working on a novel extracellular vesicle delivery technology for chronic airway diseases such as CF, COPD and congenital AAT deficiency. During discussion, the project partnership highlighted that the BREATH network was established between DkIT, QUB and UWS to focus on COPD, and was subsequently expanded to include clinical affiliates in the West of Scotland.

[26] Source: Project Progress Report 19– 'Project Specific Objectives'. This was the most recently available collated project progress report.

3.4.7 Progress towards the Project's Result Indicator Targets

It was anticipated that the BREATH project would contribute to the target of 75 peer-reviewed journal and conference publications with cross-border authorship per annum through the development of 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).

Table 3.6: Progress towards the Results Indicators

Name of Output	Programme Target (annual)	BREATH Project Target	Achieved (At April 2022)
Peer-reviewed publications with cross-border authorship	75	33	55[27]
Peer-reviewed publications with interregional authorship	Not identified	15	

As of April 2022, the project partnership had exceeded these targets in terms of the overall numbers, achieving 55 publications with cross-border or interregional authorship compared to the overall target of 48, however, the following was noted about the split:

- The number of peer-reviewed journal papers (in April 2022) stood at 16 in terms of papers supported by BREATH and where BREATH is acknowledged. However, only 9 had either cross-border or interregional authorship, albeit this was ahead of the project's projection of 6 papers at that stage. However, the project partners anticipate that the project will exceed the target by the end of 2022 or early 2023, as several papers are currently under review or in preparation. The project partnership noted that there is always a lag before the final total of papers is achieved following the end of a project.
- The project has greatly exceeded the number of conference papers with either interregional or cross-border authorship, with 46 against a target of 32. Furthermore, the project highlighted that in total the number of conference papers stands at 70 in terms of those supported by BREATH and where BREATH is acknowledged.

An overview of the journal and conference publications is provided in Appendix II.

[27] The project provided this as a collated figure, as many publications include both cross-border and interregional authorship. However, 50 of the 55 publications include cross-border authorship.

3.5 Best Practice and Learning

This section considers whether the BREATH project has resulted in any areas of 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 was central to BREATH's mission, and it was around this activity that all of the other activities revolved. It was the project partnership's view that the training of PhDs by Industry partners and collaborators was highly beneficial in the career progression of the students. Examples of specific training and engagement events which the project's research staff have benefited from include:

  - 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 attended '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;
  - Secondment in Partner laboratories; and
  - All of the PhD students delivered oral presentations and prepared posters under the guidance of their supervisors.

  In addition to receiving ongoing project support from their academic institution, each PhD student was allocated a supervisor in another area within the eligible region. It was the project partners' view that this aspect of the project supported the cross-pollination of skills and knowledge to both expedite the progress of projects and address project-specific issues that arose, contributing to the wider development of the PhD students. Including addressing any pastoral issues that arise.

- **Common PhD Training Programme** – The project partnership highlighted that the benefits of having a common training programme for 16 PhDs were appreciated by the students who said that they felt better supported than in most PhD programmes. BREATH conferences are an example of how the whole cohort of PhD students presented their work and was able to interact with a wider peer group than in many other cases. The students also maintained informal contacts across the network and were able to seek peer-to-peer advice and help. The teamwork in the project across the network was reported back by the students as being highly beneficial in job interviews.

- **Placement of a PDRF in Industry** - The project partnership indicated that the project learned that the model of providing funds for consumables to companies was dysfunctional due to the unwillingness of the companies to negotiate the complexities of the claims process. This resulted in withdrawal and/or unwillingness to participate in the project by 3 different companies. This problem was solved by instigating a new model whereby a PDRF funded by BREATH was placed in the company as it simplified the claims process.

- **BREATH had 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, and engagement with politicians at the local and parliamentary level, and with patient groups.

Learnings/Recommendations for SEUPB

The project partnership outlined the following specific recommendations/comments for the SEUPB:

- The requirement to simplify the claims process, as the requirement to get three quotes for small spend-level consumables was viewed as tedious.
- The verification and payment of claims should be completed in a timelier manner. The Project Partnership highlighted that there could be issues at the end of the project if the outstanding claims are being processed after the claims coordinator has left their job.

3.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

Discussion with the project partners indicates their view that the BREATH project has 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 was the BREATH project which was formed to investigate new treatment and diagnostic targets for COPD, which is highly prevalent within the Eligible Region.

Over the 18 months before 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 has added significant value to the quality of the research undertaken and also added value to the training experience of the emerging research talent in the Programme.

To facilitate the implementation of the project on a cross-border basis, the project partners note that they developed a shared vision and project goals and created a shared Management Structure[28], appointed a shared Project Coordinator (PC), jointly supervised the PhD projects[29], make joint conference presentations, and intend to issue publications on a shared basis. In addition, one of the PDRFs that was recruited was a Medicinal Chemist, shared between DkIT and QUB. In the project partnership's view the focus on cross-border collaboration also had a very positive effect on bonding the researchers on the project (both students and PIs) together in a focused and purposeful way.

In addition, it was highlighted that access to clinical samples and critical expertise from QUB was a key benefit to the collaboration for DkIT and UWS, raising the quality of research by feeding COPD patient samples directly into the student experimental projects. DkIT's expertise and track record in smooth muscle physio/pathophysiology provided an early accelerator for COPD myography research at UWS and was made particularly valuable by the placement opportunity occupied by a UWS PhD student in the DkIT research facility.

The Project Partnership noted that there was minimal engagement with other projects funded under the INTERREG Research and Innovation Measure, other than engaging in several informal meetings with the other INTERREG VA project managers, however, the following was noted:

- The BREATH Lead was on the Cross-border Healthcare Intervention Trials in Ireland Network (CHITIN)[30] Project Steering group.
- The BREATH Lead also presented at the Online Evaluation Workshop for Objective 1.1 Projects in March 2022, along with 3 other Interreg Projects (the Centre for Personalised Medicine, the Eastern Corridor for Medical Engineering and the North West Centre for Advanced Manufacturing).
- BREATH partners had dialogue with other projects at various showcase events (e.g. in Brussels, Edinburgh etc.), but this interaction was not to any 'great extent'.

3.7 Impact on Business and Industry

This section considers the impact of the BREATH project on businesses and industry within the eligible region.

Three industry partners, Almac Discovery, OmniSpirant and pHion Therapeutics, received financial support through the project. The project partnership outlined that the participant companies found the claims process too onerous and that they were not willing to gather three quotes as part of the procurement processes required. It was therefore agreed (with the SEUPB) that researchers would be placed in participant businesses, which simplified the claims process.

BREATH placed PDRFs in the 3 businesses (Almac Discovery, OmniSpirant and pHion) to carry out collaborative projects between these companies and BREATH PIs located in QUB and DkIT:

- There was a BREATH-funded PDRF with Almac Discovery. In addition, a QUB academic was also working between BREATH (QUB) and Almac Discovery, partly funded by a UKRI (MRC) Innovation Scholarship and this work was to continue beyond the end of the project to the end of June 2023. The two individuals worked in close partnership and together they were involved in significant technology transfer across the partners.

[28] This involved quarterly meetings of the Management Board (MB) to review the progress of the project against its targets. The MB comprised a representative from each Institute and the Project Coordinator, and was responsible for overall management (commercialisation, financial and administrative, including the Partnership Agreement and contract) of the BREATH consortium.
[29] Each PhD student had a main Supervisor in one site and a co-supervisor in a cross-border or interregional site where they could complete a laboratory secondment (albeit only four students were able to complete a secondment as a result of the impact of the Covid-19 pandemic). The progress of the PhDs was monitored by the Scientific Supervisory Board (SSB).
[30] The CHITIN project is funded through the EU's INTERREG VA Programme Priority Axis 4 Health.

- A BREATH QUB PhD was the PDRF in pHion and was transferring expertise gained through her post-graduate studies to the business.
- A BREATH-funded PDRF with OmniSpirant.
- In addition, a BREATH QUB PhD was appointed as a project leader with another of the business partners (not receiving financial support), Axis Bioservices.

Whilst the work was ongoing (as of April 2022), the project partnership outlined the following outputs/outcomes:

- The identification of a potential new clinical target as a result of the collaboration with Almac Discovery.
- Together with partners at QUB, OmniSpirant has submitted two collaborative funding applications, based on the collaboration undertaken as part of the BREATH project: one to the EU EIC Pathfinder Programme (€4m) and a second to the Path to a Cure Programme, Cystic Fibrosis Foundation USA ($1.5m).

In addition to the financial support provided to three businesses, seven businesses (inclusive of the 3 receiving financial support) received non-financial support, as follows:

1. Almac Discovery
2. pHion Therapeutics
3. OmniSpirant
4. Axis Bioservices
5. Causeway Sensors
6. Raptor Photonics
7. Biogen.

Further to the businesses listed above, the BREATH project partnership indicated that they had collaborated with other businesses, including:

Company	Nature of engagement
Teva	Provided training and sponsored prize
GSK	Provided training & hosted a 2-day industry visit
Chiesi	Provided training; sponsored BREATH seminar & dinner
Prior Medical	Expression of interest for a future research collaboration Attended BREATH conferences
Mylan	Discussed possible training by BREATH for staff
Fusion Antibodies	Discussions regarding potential partnership; but not progressed
AstraZeneca	Reciprocal presentations of PAR2 data under CDA – discussion ongoing
Analytical Engines	Discussion re potential research collaboration; not progressed.
Norbrook Laboratories	The research proposal was discussed but had not progressed
Boston Pharmaceuticals (USA)	Research collaboration & knowledge exchange. Two consecutive grants were awarded.
Merck	Potential research collaboration. Knowledge exchange.

The project partnership noted that there was a lot of collaboration between the academic institutions and industry partners, which has contributed towards enhancing the businesses' research and innovation capacity.

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

3.8.1 EU Cohesion Policy and EU2020 Objectives

The BREATH project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and enhancing the competitiveness of SMEs.

The BREATH project continues to offer the potential to contribute to the SMART Growth: Developing an economy based on knowledge and innovation key priority identified within the Europe 2020 Strategy for Growth. The project partners suggest that the project has contributed to the further development of the Regional Knowledge Economy through the development and implementation of 16 individual and bespoke R&I projects that sought to address health and social issues associated with COPD through the development of innovative new products, processes and treatments, and engagement with industry.

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.

3.8.2 The Atlantic Strategy

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

3.8.3 The Horizontal Principles

The BREATH project partners consider that the project has served to contribute (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	The BREATH project partners suggest that BREATH contributed 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 advised that they complied 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 the 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 its dedication to promoting and implementing equality of opportunities in teaching-learning, research and working environment. In addition, Project Partners offered a range of equality and diversity training to all staff and students.

	The Project Partners note that they have taken appropriate measures to ensure that no discrimination occurred based on gender, 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 candidates' 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 concerning gender and other aspects of equality. Applications were 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 worked with female 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 ensured the use of gender-neutral language in all documents and will integrate a gender dimension in public outreach actions.

3.8.4 Contribution to Other Strategies

Given the BREATH project's focus on research, innovation and health, the project partners consider that the project aligned with and contributed to:

- EU policy to reduce risk factors associated with chronic diseases such as COPD[31] and also addresses concerns raised by the European COPD Coalition regarding the lack of a concerted focus from the EU on chronic diseases (http://www.copdcoalition.eu); and
- Several 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 outlined 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'*. • **Northern Ireland: Economic Strategy** which planned 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)** stated that government would invest in skills and training to *'increase capacity to educate, develop deploy and retain talent and encourage their delivery in partnership with enterprise'*.

[31] http://ec.europa.eu/health/major_chronic_diseases/policy/index_en.htm

	• **Innovation2020 (Ireland)** described how R&D, science and technology would 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 enterprises; - Undertaking excellent research with relevance and impact on the economy and society; - Developing a strong, innovative and internationally competitive enterprise base; - Maximising the 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'** stated *'Economic growth improves health, which also significantly enhances economic productivity and growth'*. • Furthermore, a **COPD Position Paper** (Royal College of Physicians of Ireland, 2014) stated 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)** identified that Scotland's ambition was 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** sought to foster a culture of innovation by: - 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 aimed that by 2020 everyone was able to live longer, healthier lives at home.

In summary, the Evaluation Team is of the view that the BREATH project has contributed to a range of strategic imperatives that existed across the eligible region.

3.9 Barriers to Cross-Border Co-operation

The BREATH project partners did not identify any barriers to cross-border co-operation that the priority axis is not addressing.

3.10 Potential Legacy Impacts

The BREATH Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- The project partnership anticipates that the project will lead to results beyond the lifetime of the programme, in the following ways:
  - There will be further publications beyond the lifetime of the project.
  - There is a legacy from the BREATH project trainees who have taken up employment, in both industry and academia.
  - A Clinical network has been established in the West of Scotland.
  - A Public Engagement programme has improved awareness of COPD and will continue beyond the end of the project.

- The partners further consider that one of the most important elements of their exit strategy is the creation of a step-change in COPD research in the Region. This is being 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 of researchers that would not be possible without investment from INTERREG.
- The project partnership noted that collaborations will continue across the network and partners will jointly seek funding from future funding calls (e.g. North-South fund; Peace Plus etc.). In addition, the project partners will seek to further support their company partners through applications for R&D funding (Invest NI), Knowledge Transfer Partnerships (UKRI) or collaborative studentships.
- The project partnership highlighted that the project has had a strong influence on future policy, especially in the Scottish Parliament where the BREATH programme has been singled out and highlighted by MSPs from the floor on at least five occasions in debates over the last four years, and motions were raised twice to commend BREATH activity in SW Scotland.

  Additionally, BREATH is now invited members of the Cross-Party Group on Lung Health, to advise Scottish Parliament on respiratory health in disease across the nation, for example in reviewing the National Respiratory Care Action Plan (2021-2026). BREATH has also been central to discussions, since 2018, regarding the potential creation of a Centre of Excellence on Lung Health in SW Scotland, which has been featured in a two-page article in the Sunday Post (a national paper in Scotland).

  The BREATH Leads in DkIT, QUB & UWS attended a showcase event in the European Parliament in November 2017 where they showcased BREATH. The project partnership had face-to-face discussions with MEPs. BREATH also attended the All-Island Civil Dialogue on Brexit in April 2018.

4. NWCAM - NORTH WEST CENTRE FOR ADVANCED MANUFACTURING

4.1 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.

4.2 Project Overview

4.2.1 Rationale for the Project

The North West Centre for Advanced Manufacturing (NWCAM) project aimed 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, concerning 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[32] had identified the benefits of 'Innovation Brokerage'. The main task of the Innovation Broker was 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.[33]
- The importance of the regional HLS 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"*[34].

The project partners considered that these opportunities were particularly key to the eligible region, which had 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 HLS 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.

[32] 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
[33] http://www.innovationunit.org/sites/default/files/Honest%20Brokers.pdf
[34] http://matrixni.org/wp-content/uploads/2015/02/MATRIX-life-and-health-sciences-foresight-report-2015.pdf

4.2.2 *Project Partners*

NWCAM was led by Catalyst Inc (the trading name of Northern Ireland Science Park Holdings Ltd) and involved several academic and industrial partners, including:

Project Partners	**Industrial Partners / Beneficiaries**[35]	
• 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.	• Abbott; • Armstrong Medical; • Laser Prototypes Europe; • GSK Stiefel; • Leckey	• Nuprint; • Denroy Plastics Ltd; • axial 3D; • Causeway Sensors; • Clyde Biosciences[36].

The project partners considered that the capabilities of the institutions were complementary. For example:

- One of NWCAM's projects required both knowledge of polymer materials and processing (UU) as well as process control (ITS). The partners noted that changes in process parameters such as cooling rates had the potential to significantly influence the structure and properties of finished parts. For this project, UU determined how process influenced structure and properties and identified the key influencing process parameters; whilst ITS determined the process control necessary to ensure a robust process and product of consistent dimension and properties.
- Another project required expert knowledge in polymer materials and processing (UU) as well as machine development and control systems (LyIT). It was considered that it would not be possible for LyIT to design and build such a machine without knowledge of the polymer materials to be processed and their particular processing requirements (e.g. heating, cooling, shear rates etc.).

4.2.3 *Project Overview, Objectives and Activities*

The North West Centre for Advanced Manufacturing (NWCAM) project aimed 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 Precision Engineering and Manufacturing (PEM) Centre at Sligo Institute of Technology; and CoLab at Letterkenny Institute of Technology; co-ordinated by Catalyst Inc.

The project's Vision was:

"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 was 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.[37]

[35] Other businesses that were initially engaged with the project included Randox Laboratories, Sphere Global and Bemis Healthcare Packaging.
[36] A modification request to include Clyde Biosciences as an additional industrial partner/ beneficiary submitted in October 2019 was accepted in July 2020.
[37] 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.

It was anticipated that this would see the development of a virtual cross-border Centre for Advanced Manufacturing with a focus on four thematic areas for application within the HLS Sector:[38]

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 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 was 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 the 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 was a research competence area of UU and ITS.
3. Additive Manufacturing	Also referred to as 3D printing, additive manufacturing is any of the 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 was a research competence area of UU and LyIT.
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 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 was a research competence area of UG and ITS.

[38] 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 concentrated its efforts on a select number of advanced manufacturing competence areas, in which the academic partners were previously engaged in high level research activities.

NWCAM's Letter of Offer identified the project's objectives as being to achieve the following:

1. To increase the level of cross-border collaboration across the Region in the area of applied Advanced Manufacturing R&I.
2. To increase the number of regional HLS sector companies (including supply chain) engaged in commercially-driven cross-border Advanced Manufacturing R&I.
3. To develop the regional economy through the development of new products and/or processes (TRLs 2-to-6) within the HLS Sector; developed as a result of the application of Advanced Manufacturing technologies.
4. To increase awareness of the potential of Advanced Manufacturing as an enabling technology within the HLS Sector and other sectors key to the region's current and future economic success.

To achieve their project objectives, the project partners advised that they would undertake the following activities.

1. **Coordination 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) met every quarter. The purpose of these meetings was to ensure that all project members remained updated and opportunities for cross-research synergies were identified as early as possible. These meetings were chaired by the PI. Related reports were coordinated for presentation to the Project Board. This entity also met quarterly and was chaired by Catalyst Inc's (C-I's) Financial Director.

2. **Management of 16 R&I Projects with 10 Regional Industrial Partners** - To achieve the stated objectives, the Project Partnership implemented 16 R&I projects in partnership with ten regional companies within the Regional HLS sector (including supply chain companies). The projects encompassed the four specific areas of Advanced Manufacturing; Advanced Polymers; Additive Manufacturing; Nano-manufacturing; and Sustainable Manufacturing.

   An overview of each of the 16 R&I Projects is outlined in Appendix IV. The implementation of the projects required the recruitment and management of 13 PhD students and 11 PDRA staff.

3. **Innovation Management Activities** - The 16 R&I projects aimed to create 16 new products and or processes. Central to the suggested operation of the project was the role of C-I, to forge a more effective link between academic and industrial partners and as such, they led the Innovation Management dimension of the project. Arrangements were put in place for IP management which covered 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 were included to manage the process of IP. IP was managed through all stages of the project, with significant input at the proposal stage, which continued through grant preparation, project implementation, exploitation and dissemination of results stage and conclusion of the project. These activities were managed by two C-I appointed Innovation Brokers, who were responsible for providing related quarterly reports to the Project Team and Project Board. The partners adopted the Innovation Management IP agreement model utilised within the Invest NI-supported Competence Centres.

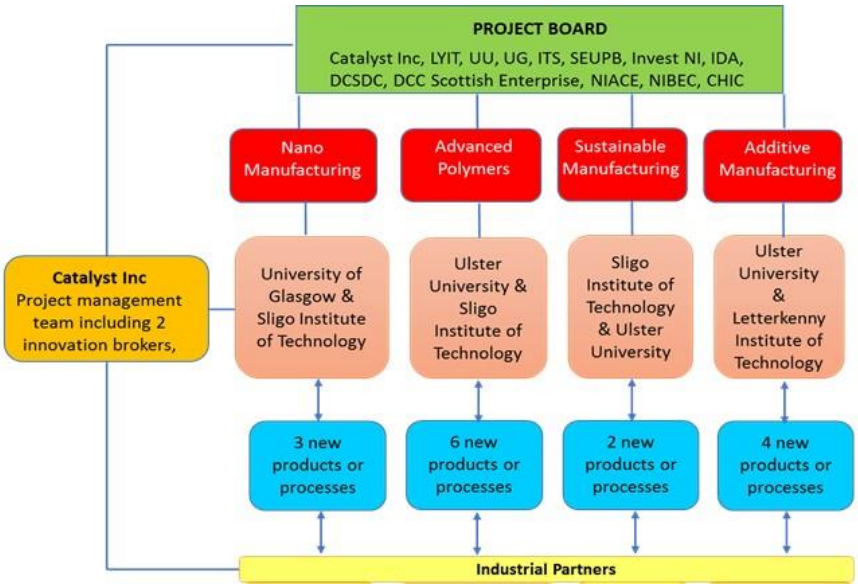
4. **Preparation of 30 peer-reviewed journal articles with cross-border authorship** – It was anticipated that these would illustrate the commercially beneficial application of Advanced Manufacturing technologies within the HLS and other key regional sectors. Each Thematic Lead was responsible for coordinating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

To deliver the project activities, eight work plans were developed, as follows:

Table 4.1: 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

A diagrammatical overview of the NWCAM Project is presented below:

Figure 4.1: Overview of the NWCAM Project



4.2.4 Anticipated Outcomes & Results

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

It was envisaged that the virtual centre would span the Region but operate out of the North West; thereby seeking to redress the underinvestment in R&I in that part of the Region; and provide access to cutting-edge research expertise to several Tier 1, 2 and 3 companies located there. Eight industry partners have been identified and participated in the co-design of the research programme, together with the academic partners.

As noted above the aim of the 16 R&I projects was to create 16 new products and or processes.

4.3 Project Expenditure to July 2022

The NWCAM project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €8,518,406 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,779,853.

In September 2021, the SEUPB issued a revised LoO (dated 20th September 2021) which approved a project extension, to 31st May 2022, and the reallocation of the budget between categories. The LoO also updated the project's targets.

In May 2022, the SEUPB issued a further revised LoO (dated 20th May 2022) offering a grant of up to a maximum of €8,513,230 (ERDF + Government Match Funding) to be expended and claimed by 30th June 2022, towards the total anticipated project costs of €8,779,853, which in addition to lowering the overall maximum grant offering and extending the project end date also approved a reallocation of budget between categories. The LoO also updated the project's targets as shown in Section 4.4.4.

Further to the above, the Evaluation Team's review of SEUPB's EMS indicates that there has since been a further reallocation of budget between categories, as reflected below. As of July 2022, the project reported total actual expenditure of €8,366,831 equivalent to 95% of the total project budget, however, whilst the project was considered to have been completed at the end of June 2022, this may not reflect the final expenditure position due to the timing of submission and verification of final claims.

Table 4.2: Project Costs – Anticipated and Actual July 2022 (€)

Summary Budget	Anticipated Total	Total Actual Expenditure[39]	% of the total budget
Staff Costs	4,548,716	4,335,113	95%
Office and Administration Costs	1,702,331	1,632,412	96%
Travel and Accommodation Costs	98,611	73,135	74%
External Expertise and Services	1,857,170	1,747,548	94%
Equipment Costs	573,025	578,624	101%
Total	**8,779,853**	**8,366,831**	**95%**

Discussion with the NWCAM project partnership in April/May 2022 indicated that they were anticipating a slight underspend, as a result of some contracted Research Associates (RAs) leaving earlier than anticipated to move onto other contracts/permanent positions, reduced travel as a result of Covid-19 and delays that had impacted some potential commercialisation activities (e.g. monies to undertake disclosure searches etc.).

[39] Source: SEUPB's EMS 18th July 2022

4.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the NWCAM project's key achievements 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, the project's ability to contribute to the achievement of the Specific Objective.

4.4.1 Key Activities Undertaken (to June 2022)

The Evaluation Team's review of the NWCAM project partners' progress reports indicates that key activities undertaken since the second evaluation report (between April 2020 and June 2022[40]) include the following:

Table 4.3: Key Activities

Period	Dates	Key Activities /Points of Note
13	1st April 2020 – 30th June 2020	• Several articles were produced and issued to promote both the project as a whole and specific effort made by individual NWCAM partners to address the pandemic. NWCAM was featured in the EU Summer SEUPB magazine where the HLS Survey was highlighted. This study and report were designed, delivered and published by the Innovation Broker role within NWCAM. • The University of Glasgow submitted a conference paper to FLEPS2020 (an international conference) describing the selective printing process. • Furthermore, a journal paper describing the contact printing system was in development.
14	1st July 2020 – 30th September 2020	• An e-zine was released for Summer 2020 and emailed to 208 newsletter subscribers. The e-zine provided an update on NWCAM projects, highlighted NWCAM researchers, the project's Covid-19 responses and some topical upcoming online events. • Also, within this period a press article was written and published to advocate NWCAM partners' efforts in the fight against the pandemic. This article was circulated through SyncNI and hosted online on the NWCAM webpage. It was also featured in the Catalyst newsletter to reach a wider audience. • The NWCAM project manager and SPIRE2 commercialisation manager based at Ulster University collaborated to design and deliver commercialisation-focused training for INTERREG VA PhD students.
15	1st October 2020 – 31st December 2020	• A report providing an annual review of the regional benefits to the North West, as a result, of NWCAM research was completed. • Co-designed PhD training in line with Marie Curie Research Training Networks (RTN) principles was delivered which focused on industrial engagement skills and strategies to adopt more commercially-focused research activities. • NWCAM collaborated with the SPIRE2 project to offer multi-disciplinary working sessions and expose the PhD researchers to new insights relating to research disciplines that they would not otherwise have had exposure to. The sessions in October and November received positive feedback from the training participants. • A range of review reports was delivered relating to the full 2020 period. These included reports on emerging benefits, an annual summary of research outputs from individual work plans and a review of the research to ensure it remained commercially relevant.

[40] 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 (July 2022). The most recently available collated Project Progress report for the project was for period 20 (January – March 2022), with key achievements outlined in subsequent period taken from partner progress reports.

Table 4.3: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
16	1st January 2021 – 31st March 2021	• Institute of Technology Sligo had a review paper published. • Catalyst's research management team developed plans for an NWCAM academic conference.
17	1st April 2021 – 30th June 2021	• The last project Academic Partner Meeting was held. 38 participants were in attendance and 14 researcher presentations were hosted. The researcher presentations gave an overview of the work that they had undertaken and emerging research findings.
18	1st July 2021 – 30th September 2021	• The NWCAM academic conference (Advanced Manufacturing: Transforming the Future of Health and Life Sciences) was held on 1st September. The conference was hosted using a hybrid approach by streaming a mixture of pre-recorded and live segments on Zoom. Submissions to the conference were peer-reviewed and assessed to ensure the conference submissions had academic rigour. A dedicated webpage was created to host the cross-border submissions that were presented and accepted at the conference. • During this quarter the project focused on several key areas including promoting gender equality within the sector, showcasing early career researchers, and promoting the range of benefits of research and innovation supported through EU funding and knowledge sharing between a range of innovation-focused individuals and companies.
19	1st October 2021 – 31st December 2021	• The project's Innovation Brokers created a report to highlight emerging benefits within the Northwest region.
20	1st January 2022 – 31st March 2022	• On 23rd March 2022 along with the NWCAM Board meeting, an in-person event was held at Catalyst, Belfast that marked the official closure of the NWCAM project. Minister Gordon Lyons from the Department for the Economy provided a pre-recorded clip which was shown on the day. • The project created three 'legacy' videos to showcase the project. One video focused on the industry perspective, the second on the academic perspective and the third highlighted the impact and successes of the project. A press release was also created to mark the closure of the project.
21	1st April 2022 – 30th June 2022 (From Partner Progress Reports)	• A post-project evaluation for the project was completed. • Final project reports were designed. • An article was written about European student placements to promote diversity of skills within Catalyst tenant companies and to develop knowledge-sharing initiatives. • A social campaign was delivered including participants' feedback and shared with a wide range of stakeholders, to promote the project, and the programme and support local R&I activity carried out by the NWCAM partners. • An article was written to discuss and outline the lasting impact of NWCAM on Catalyst.

4.4.2 External Impact Factors

Discussion with the NWCAM Project Partners indicates that the project encountered several issues during its delivery, that in combination serve to slow progress towards the achievement of its output indicator targets (e.g. the number of PhD years). However, encouragingly, none of the issues encountered ultimately had any substantive adverse impact on their overall achievement. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the NWCAM Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, project partners or direct beneficiaries started working remotely and/or had furloughed staff. This included Glasgow University furloughing staff, which had an impact on the number of research years for that period;
- The project lost access to laboratories across each of the academic partners, and to testing and development sites (within the industry partners) which had a substantial impact on progress. Whilst some PhD students had already completed sampling and testing and therefore were able to work from home, many had not. However, the project's academics continued to engage with PDRAs and PhD students and with NWCAM partner companies through online means to provide project updates. Other activities were also able to be progressed remotely including:

  - Identifying opportunities for cross-border paper content and conference/journal preparation including literature reviews, methodologies etc.
  - Desktop work focused on market analysis studies, design and simulation activities, and data modelling activities.

- In some cases, businesses and innovators within the NWCAM ecosystem changed their 'normal' working patterns to focus on repurposing their manufacturing capabilities in response to the COVID-19 pandemic. The project partners consider that this served to create a 'unified sense of purpose' during a turbulent period.
- The project partnership increased the number of project management meetings to ensure the timely transfer of updates between partners to understand progress, obstacles and new risks to each project and each partner, which helped to maintain connections and communications between all involved in the project.

In recognition of the delays experienced, and as outlined in Section 4.3, to allow the NWCAM project further time to complete activities, the project received a six-month extension to 30th June 2022.

Ultimately, beyond some delays in the implementation of projects, the NWCAM project partnership advised the Evaluation Team in May 2022 that the steps they took during the periods of lockdown during the pandemic (working remotely and moving some activity online) meant that, for the most part, there was no impact on the project ultimately achieving most of its deliverables (except for its result indicator target).

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit did not have any substantive impact on the project overall, albeit some partners did face supply chain issues (e.g. delays and cost increases).

Whilst Brexit did not have a substantive impact on the NWCAM project, the partnership noted their concerns that its outworkings had the potential to impact the likelihood of funding being available for similar cross-border projects in the future.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the NWCAM project included:

- **IP issues impacting businesses' engagement on the project** – The project partners noted that at the outset, it had been anticipated that Randox Laboratories Ltd and Bemis Healthcare Packaging would receive support through the NWCAM project. However, after the two businesses became aware 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. This IP issue also prevented a further business (Thermo Fisher, based in Scotland), which was anticipated to provide substantive input into one of the research projects, from engaging in the project. Whilst the anticipated partners were ultimately replaced, the withdrawal of those businesses meant that some delays were encountered;[41]
- **Delays in the recruitment of research staff** - The NWCAM project partners note that there were considerable delays in recruiting the project's PhD student cohort and post-doctoral research positions. According to the project partners they experienced 'a general lack of appetite' from prospective domestic research staff applicants and, of those that did apply, a considerable number were deemed not to be of the requisite quality that the project required (e.g. in terms of their skill sets and/or experience of working with industry). Consequently, the Project Partners sought applications from potential international PhD students (using the 'Find a PhD' online platform). However, whilst this proved successful in securing applicants, there were delays in these students securing the requisite visas. Nonetheless, the NWCAM Project Partners advise that most of the supported projects were able to progress during this period, with preliminary work 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 were several changes to the profile of the project's research team during the delivery period. Examples of changes include a change to the lead PI within UU, a PhD student going on maternity leave, Post-doctoral research staff returning to their home country or moving to a different post within the University or leaving the University;
- **EU and University Procurement requirements hindering the progression of research** - According to the NWCAM project partners, the progression of research was hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed to conduct research;
- **Delays at UoG** – The University of Glasgow encountered several specific setbacks including both a fire on-site and flooding.

4.4.3 Variation to Planned Activities

Discussion with the project partnership indicates that a small number of activities/deliverables regarding PhD thesis were not implemented in the way or extent that was originally proposed. As a result of the aforementioned delays (largely resulting from the onset of the Covid-19 pandemic), some PhD students were still in the process of completing their thesis at the project end date (i.e. June 2022). Consequently, the project completed summaries of these in the absence of the full thesis being available at the end of the project period.

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

4.4.4 *Progress towards the Project's Output Indicators*

As of June 2022, the NWCAM Project Partnership was of the view that it had fully achieved its anticipated (approved) project outputs, with:

- 10 enterprises receiving support/non-financial support (CO01 and CO04), cooperating with research institutions (CO26) and participating in cross-border, transnational or interregional research projects (CO41).
- 4 enterprises receiving grants (CO02) (against the project's original target of 2) (Causeway Sensors, NuPrint, Axial 3D and LPE);
- Circa 105 research years completed (against the project's original target of 98.5); and
- The 4 partner research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 4.4: Progress towards Output Targets

Output Code	Description	Priority Axis 1 target		NWCAM target[42]	Progress as of June 2022[43]	Variance against project target
CO24	No. of new researchers in supported entities		T1.3.1	29.50	29.51	-
			T2.3.1	25.50	28.66	+12%
			T3.3.1	21.50	23.99	+12%
			T4.2.1	13.00	13.59	+5%
			T6.1.1	9.00	9.11	+1%
		514		**98.5**	**104.86**	**+6%**
CO01	No. of enterprises receiving support	20		9	10	+11%
CO04	Enterprises receiving non-financial support	20		9	10	+11%
CO26	No. of enterprises cooperating with research institutions.	10		9	10	+11%
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects.	10		9	10	+11%
CO02	No. of enterprises receiving grants	10		2	4[44]	+100%
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects.	5		4	4	-

[42] The targets for outputs CO01, CO04, CO26 and CO41 were revised (from 8 to 9) in the LoO dated 20th September 2021.
[43] Source: Discussion with the project partnership and Project Progress Report 21 – 'Total reported'. This was the most recently available collated project progress report albeit it was described as being 'in progress'.
[44] Discussion with the project partnership, and the project's presentation to SEUPB in March 2022, albeit the most recent progress report states 0.

4.4.5 Key Achievements (to May 2022)

Discussion with the project partners indicates that they consider the following to be amongst the NWCAM project's key achievements (as of May 2022):

- The development of the PhD students, and the knowledge economy - The project partnership consider that the PhD students involved in the project benefited from the cutting-edge methods they experienced first-hand while working alongside the industry partners, becoming skilled in high-value areas such as 3D printing, injection moulding and laser modelling. Throughout the lifetime of the NWCAM project, a full range of PhD training was facilitated by Catalyst to develop researchers' 'softer skills' that might prove useful for their future careers. For example, CV & Career Coaching sessions were held in April 2021, offering one-to-one support to the PhD students.

  The PhD students also benefited from the Marie Curie Innovative Network Allowance for research, training and networking activities. The students were encouraged to identify training opportunities outside the standard PhD training and were subsequently able to share their learnings with peers. In addition, the Doctoral College at UU offered NWCAM PhD students access to training modules, which meant that the students based in the partner research institutions had increased opportunities to complete training modules.

  NWCAM also collaborated with (the INTERREG VA-funded) SPIRE2 project to offer multi-disciplinary working/training sessions (for example, on topics such as commercialisation and career development). This activity sought to provide the PhD researchers with new insights into new research disciplines that they would not have otherwise had exposure to.

  PhD students noted the following about their involvement in the NWCAM project:

  > *"Being a part of NWCAM allowed me to interact with people from different backgrounds, both in academia and industry. I received opportunities to acquire knowledge, skills, and creativity. The multidisciplinary research opens up huge inspiration to utilise technology in new ways."*
  >
  > *"My involvement in the NWCAM project offered me the opportunity to develop invaluable new skills in areas such as electrospinning, printing material for point-of-care, and wireless and disposable sensors, which I feel will be beneficial for my career. I hope to be able to advance this experience to tackle challenges such as global warming, the energy crisis, food quality monitoring, and m-health by combining my chemistry background and interest in materials investigation and modelling through density-functional theory (DFT) and computational chemistry".*

  The project partnership outlined the following position of participant PhD students as of May 2022:

  - c.58% had finalised their PhD and were now employed in a research position (50%) or an industrial role (c.8%);
  - 15% had finalised their PhD, but their progression was not known; and
  - c.27% were finalising their PhD.

- The project's work with industry and the impacts achieved for the industrial partners. The following example was cited - Armstrong Medical, a specialist manufacturer of anaesthesia and critical care products based in Coleraine (NI), is understood to have commercialised an innovative respiratory breathing circuit for life support ventilation that was developed in collaboration with Ulster University through an NWCAM project. The Armstrong Medical AquaVENT® VT breathing circuit reduces medical waste (as the older tube needed to be replaced every 8 hours, whilst this new product only needs to be changed every other day) and relieves hospital caregivers of some aspects of the continuous monitoring of the equipment in use. In addition, Armstrong Medical recruited a sales post specifically to promote the new product. Further industrial impacts are discussed in Section 4.7 and Appendix VI.

- Whilst difficult to measure, the NWCAM project partners consider that the researchers involved in the project are now more willing to work with industry, noting that having worked closely with industry through the project (and experiencing the benefits of the industry-led research), academics were now asking 'what does industry need' when considering the research that they could undertake.
- To facilitate the growth of the HLS innovation ecosystem, the NWCAM project commissioned a survey of HLS-focused companies across the region. The purpose of the survey was to achieve an understanding of current, and future industry R&D interests, needs and challenges; and to gauge awareness of Advanced Manufacturing – highlighting its potential as an enabling technology to enhance industry competitiveness, efficiency and productivity. Key results indicated that:

  - 78% of respondents confirmed that they would be interested in engaging in cross-border collaborative Advanced Manufacturing R&D;
  - 97% agreed that there was an engineering skills shortage in the region; and
  - 77% reported an awareness of Advanced Manufacturing as an enabling technology with the potential to improve commercial performance.

- The project partnership considered that the project developed meaningful connections with a range of wider stakeholders such as DCSDC, Invest NI, Manufacturing NI and DfE. Indeed, it notes that during February 2021, the Department for the Economy, through Catalyst, offered the NWCAM NI-based industrial partners, the opportunity to compete for a share of a £96,000 funding pot to further develop their NWCAM research and development projects and to aid business recovery in a post covid world. The funding was awarded to Axial3D, Causeway Sensors, Laser Prototypes Europe (LPE), Leckey and NuPrint.

4.4.6 Progress towards the Project's Stated Objectives

As reflected in Section 4.2, NWCAM's Letter of Offer identified four specific project objectives. Whilst the NWCAM project's progress reports did not require the project to monitor the extent to which the project was achieving each of the objectives, the Evaluation Team's discussions with the project partnership indicate the following:

Table 4.5: Project's Specific Objectives

Specific Objective	Commentary per the Evaluation Team's discussions with the NWCAM project
1. To increase the level of cross-border collaboration across the region in the area of applied Advanced Manufacturing R&I.	The NWCAM partners consider that the project created a virtual cross-border centre that provided applied research expertise and capabilities in Advanced Manufacturing from four research institutions to ten businesses in the HLS sector. The ten industrial partners were: Abbott, Armstrong Medical, Axial3D, Causeway Sensors, Clyde Biosciences, Denroy, GSK, Leckey, Laser Prototypes Europe and NuPrint Technologies. The Evaluation Team notes however that the extent to which individual projects were undertaken on a cross-border basis is not clear with, for example, a NI-based research institution paired with a NI-based business in many instances (see Appendix IV for details).
2. To increase the number of regional HLS sector companies (including supply chain) engaged in commercially-driven cross-border Advanced Manufacturing R&I.	The NWCAM partners consider that this objective was achieved as 10 industrial partners were involved in co-designing the research projects. The Evaluation Team notes that the extent to which the 10 businesses were involved in cross-border R&I activity before they engaged with the NWCAM project, is not known.

Table 4.5: Project's Specific Objectives	
Specific Objective	**Commentary per the Evaluation Team's discussions with the NWCAM project**
3. To develop the regional economy through the development of new products and/or processes (TRLs 2-to-6) within the HLS Sector; developed as a result of the application of Advanced Manufacturing technologies.	The project partners consider that this objective was achieved as NWCAM supported 16 individual R&I research projects across 10 industrial partners which aimed to create new products and /or processes. The Evaluation Team notes that it is difficult to determine the extent to which this objective was achieved but considers from the project overviews that each of the 16 projects was commercially focused.
4. To increase awareness of the potential of Advanced Manufacturing as an enabling technology within the HLS sector and other sectors key to the region's current and future economic success	The NWCAM project partners consider that this objective was to be measured by the development of peer-reviewed journal articles with cross-border authorship illustrating the commercially beneficial application of Advanced Manufacturing technologies within the HLS sector. The project advises that it produced 18 peer-reviewed journal articles with cross-border authorship (see Section 4.4.7).

4.4.7 Progress towards the Project's Result Indicator Target

It is anticipated that the NWCAM project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 30 peer-reviewed journal and conference publications within the HLS sector with cross-border authorship and with the potential to create economic impact.

As of May 2022, the project reports that it produced 83 peer-reviewed journals and/or conference publications, however, only 18 (22%) were cited as having cross-border authorship. Appendix V provides an overview of those publications with cross-border authorship.

Table 4.6: Progress towards Result Indicator Target	
NWCAM Target	**Progress (at May 2022)[45]**
30	18

The project partnership advised the Evaluation Team that the two ROI academic partners were only involved in 3 (of 16) research projects, which limited the opportunities for cross-border publications.

The NWCAM project partners queried the appropriateness of the Result Indicator (i.e. cross-border authorship) given the cross-jurisdictional inter-regional nature of the project design (NI/ROI/Scotland).

4.5 Best Practice and Learning

The NWCAM project partners were of the view that the industry-led model that they employed represented good/best practice and noted the following specific areas of the project's operation that they consider reflect good practice and/or opportunities for shared learning:

- **The utilisation of wider advanced manufacturing and composites facilities to support project delivery** – The Project Partners advise that IT Sligo and UU jointly utilised the Northern Ireland Advanced Composites And Engineering Centre (NIACE) facility to undertake joint testing using the facility's specialist equipment, which encouraged shared learning;
- **The utilisation of Innovation Brokers to explore commercialisation opportunities –** The NWCAM project partners consider that the role of its Innovation Brokers was key to developing a shared understanding between the academic personnel and the industry partners. Their role included

[45] Source: Consultation with the Project Partnership

developing a shared understanding of the nature of the research being undertaken and its potential industrial application and routes to market. The project partners suggest that this structure offered a 'specific built-in commercialisation focus' which they consider will ultimately help maximise the impact of the project;

- **The honest broker role played by Catalyst and its knowledge of the wider industrial landscape** – Catalyst considered that it played an 'honest broker' role that helped facilitate good working relationships between industry and academia. In addition, Catalyst advises that its understanding of the business landscape helped it identify industrial partners that would offer a good 'fit' with the academic partners and who it considers would benefit from participation in the project;
- **Rotation of the project's communication and outreach activities** - Communication and outreach activities (e.g. academic partner meetings, press releases) were rotated amongst the partners' jurisdictions to build equity, a joint sense of ownership amongst the NWCAM partners (thereby also helping ensure that the project was not perceived to be Belfast-centric);
- **The establishment of an informal 'Project Managers' Group'** facilitated open discussion concerning INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allowed for shared learning and insights that had 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 this project output was closely monitored.
- **Hosting of research outputs to promote knowledge transfer** - In terms of learning, journals and international conference papers were hosted on an open website via Catalyst on the NWCAM home page to promote open-source access and knowledge sharing throughout the region's Advanced manufacturing and/or HLS sectors; and
- **Community building** – There was positive engagement within the wider research community, including being able to signpost stakeholders to other INTERREG expertise, topical events, networking opportunities etc.

4.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between projects funded.

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:

- The industry partners' exposure to additional research facilities and expertise that would otherwise not be available on a single jurisdiction basis;
- LyIT's and UU's collaboration on one of the 16 projects, where the resourcing was split between the two organisations, helped to forge close collaboration to ensure successful project delivery;
- The facilitation of knowledge exchange and facility sharing among academics from across the eligible region, for example:
  - IT Sligo and UU used NIACE's facilities to run joint testing. IT Sligo visited facilities and conducted material testing using UU equipment; and
  - The University of Glasgow used IT Sligo's laser welding equipment.
- Enhanced relationships among the four academic institutions, which the project partners envisage will facilitate further cross-border projects.

As a result of activities carried out within the NWCAM project, Catalyst advises that it introduced a new way of working, with the creation of the 'Open Innovation' unit and a new role, Director of Strategic Business Development, to help Catalyst develop and strengthen strategic partnerships across industry, academia and government.

As noted previously, NWCAM engaged in the informal 'Project Managers' Group' which facilitated open discussion concerning INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allowed for the sharing of learning and insights that had been gained by each project manager. In addition, given the synergies between the NWCAM, CPM and ECME projects the project managers coordinated the timing and location of project events to avoid duplication in the market.

NWCAM also collaborated with SPIRE2 to offer their PhD students opportunities to participate in multi-disciplinary working/training sessions (in areas such as commercialisation and career development), which it was anticipated would provide the PhD researchers with new insights from research disciplines that they would not otherwise have been exposed to.

4.7 Impact on Business and Industry

The project partnership considers that the 16 industry-led research projects (with 10 industrial partners) that were delivered through NWCAM served to enhance the participant businesses' research and innovation capacity, and resulted in a range of positive activities and outputs.

A detailed overview of the outcomes resulting from the 16 research projects is provided in Appendix VI, with key highlights including:

- **Knowledge Transfer/Exchange** - The project provided access to expertise and provided opportunities for learning and knowledge transfer between the academic institutions and the industrial partners;
- **Development of industrial competencies** – The project partners note, for example, that NuPrint's competencies were developed as a result of undertaking a pilot project with Altnagelvin hospital concerning smart labelling for secure patient information transfer;
- **Development of eight IP disclosures (which are at different stages) and two licensing agreements** – The project partners note, for example, that as part of the 'Development of insulated medical tubing with controlled gas barrier properties' research project, the developed technology was licensed to the project's industry partner (Armstrong Medical) and they obtained regulatory approval for their new breathing circuit product 'AquaVENT VT'
- **Development of healthcare products** – It is noted that:
  - Leckey developed an operational prototype which demonstrated embedded sensors in a 3D-printed seat for comfort, heat control and pressure points;
  - axial3D repurposed its 3D printing capacity to print much-needed parts for ICU ventilators, as well as COVID-19 test kits and masks for the National Health Service (NHS) and the Health and Safety Executive (HSE);
  - Armstrong Medical launched its AquaVENT® VT breathing circuit just before the WHO declared the global coronavirus pandemic. AquaVENT® VT benefits from R&D generated through the NWCAM collaboration with UU which developed a novel method of producing tubing used to create a 'breathable' expiratory limb. The research enabled Armstrong Medical to significantly reduce the risks associated with the pooling of condensed water vapour in the tubing. The innovative step also minimised the interference by moisture on sensitive electronics on ventilators, relieving hospital caregivers of some aspects of the continuous monitoring of the equipment in use.

    This technology has now been incorporated into several critical care ventilator circuits for adult, paediatric and neonatal patients who require assistance with their breathing. By expanding the range of breathing circuits and electromedical devices that it supplies to hospital intensive care units, Armstrong Medical was able to respond rapidly to global demand for these critical respiratory devices as caregivers around the globe scrambled to secure the means by which to treat COVID-19 patients.

Armstrong Medical's Technical Director said (in July 2021) that *"The introduction of this superior product will add significant value to Armstrong's expanding portfolio of pioneering products to ensure improved patient outcomes in a critical illness setting.."*

- **Development of new materials in new sectoral areas.** NWCAM notes that Denroy Plastics worked with a consortium of local businesses to design and manufacture the Hero Shield, a plastic protective visor to guard the face. In addition, NuPrint used its technology and resources to develop a range of face shields including a CE-certified face shield that has since been used by health professionals throughout the UK;
- **Development of new processing models** - IT Sligo used AI to develop a predictive production model that aims to reduce GSK's energy utilisation. NWCAM advises that GSK introduced the model in its plant in Irvine, which resulted in a 5%-10% reduction in the plant's energy costs. It is understood that GSK plans to roll the model out into all its UK plants, with the potential to roll it out across Europe.
- **Development of two applications for Invest NI Proof of Concept funding.**

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

- Increase businesses' focus on long-term R&I planning, as opposed to short-term plans[46];
- 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. For example, as a result of the positive engagement with academics on the NWCAM project, Leckey has now agreed to take on a Knowledge Transfer Partnership (KTP) with QUB to continue that two-way knowledge exchange; and
- Increase academia's understanding of the needs of industry.

4.8 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 Cohesion Policy and EU 2020 objectives;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

4.8.1 EU Cohesion Policy and EU2020 Objectives

The NWCAM project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and enhancing the competitiveness of SMEs.

The NWCAM project has helped 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 consider that each of the 16 NWCAM-supported projects has contributed to the development of the Regional Knowledge Economy.

[46] The project partnership "interviewed" the industrial partners involved at the outset of the project and it was discovered that their R&I plans were very short term, whereas NWCAM advises that the industrial partners have now adopted a medium-longer term perspective on the implications of R&I on their business.

4.8.2 The Horizontal Principles

The NWCAM project contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable Development	The Project Partners each agreed to align their activities with the Lead Academic Partner's (Ulster University) Environmental Sustainability Policy. This stated 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 and hence the Project Partnership was 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.
Equal opportunities and non-discrimination	The Project Partners advised that they were committed to ensuring that equality was central to all project activities. They considered that this would ensure compliance with regional equality legislation, including that about Northern Ireland; the Border Region of Ireland; and Western Scotland. As a Designated Body, Catalyst (Lead Partner) was required under Section 75 of the Northern Ireland Act (1998), to conduct its operations (which extended to the proposed Project) with due regard to the need to promote equality of opportunity: • Between persons of different religious beliefs, political opinions, racial groups, 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 also noted that equality considerations were central to the project's design. The location of the NWCAM project within the North West was suggested to be a deliberate attempt to redress the lack of R&I investment in this more peripheral and rural area of the Region.
Equality between men and women	Catalyst notes that it is committed to the promotion of gender equality and subscribes to the view that diversity is a performance driver. As such, it ensured that the recruitment of all project staff, including the four Management and Administration roles; and PhDs and PDRAs, was undertaken in line with the relevant legislation.

4.8.3 Contribution to Other Strategies

The NWCAM project aimed 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 contributed to several economic and innovation-related strategies in each of the three jurisdictions, including:

Europe	• The **EU's SMART Specialisation Strategy** in that the NWCAM project facilitated a focus on two of the region's core sectors; HLS and Advanced Manufacturing.
Northern Ireland	• **The NI Draft Programme for Government 2016-2021** – Amongst the PfG's priorities was 'Developing a competitive, Regionally balanced Economy'. The primary purpose of Priority was to achieve long-term economic growth through actions including "stimulating innovation, R&D and creativity and supporting

	conditions, where a greater number of businesses are competing successfully overseas". It highlighted the importance of North / South linkages to help deliver upon these priorities and a commitment to work closely with Ireland in ways that were both practical and mutually advantageous. • **Regional Innovation Strategy Action Plan 2014-2025 (DfE)** - The Strategy outlined the requirement to address the main barriers to innovation, which included factors such as skills, issues, knowledge and cost. It included four key actions to maximise knowledge exploitation across Northern Ireland, one of which was to support the expansion of Catalyst Inc (C-I).
Ireland	• **Action Plan for Jobs (DJEI)** - The 2016 Action Plan highlighted the importance of R&I to build a competitive advantage and drive job creation. Concerning manufacturing specifically, the Plan outlined 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 established a vision that by 2020 Ireland would 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 was 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 € 5 billion would be invested per year in R&D by the private and public sectors by 2020. This represented an almost doubling of current levels of investment (€2.9billion in 2014). • **Sharing our Future: Ireland 2025 (Forfas)** - As part of the sharing our Future report, Forfás confirmed that R&I was 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 2015-16 Programme for Government (PfG), the Scottish Government stated 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 established the ambition to help to make Scotland more globally competitive. Of particular relevance to the proposed project, a key priority was Innovation – Within its Business Plan, Scottish Enterprise suggests that innovation "is the lifeblood of long-term economic success". The Plan suggested that the Scottish Government would 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 has contributed to a range of strategic imperatives that existed across the eligible region.

4.9 Barriers to Cross-Border Co-operation

The NWCAM project partners indicate that they encountered several barriers to cross-border co-operation that the priority axis did not address. These included:

- Visa restrictions relating to some (prospective) researchers – depending on their country of origin and type of visa;
- The unknown potential 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 mindset of partners' wider opportunities.

4.10 Potential Legacy Impacts

The NWCAM Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- There had been spin-off activity from NWCAM. For example, a new Manufacturing and Engineering collaborative network has been established in the North West, primarily in the Derry City and Strabane Council area, known as GEMX – Generating Engineering and Manufacturing Excellence. NWCAM industrial partner, Nuprint Technologies is the lead partner of this new venture that is supported by Invest NI through its Collaborative Growth Programme. The network is made up of engineering and manufacturing businesses that are working collaboratively with local further and higher education institutes and Derry City and Strabane District Council to promote skills and employability in the industry.
- The invention disclosures will continue to be reviewed, and there is potential for further work and results beyond the lifetime of the project.
- The project partnership highlighted that the relationships developed through the NWCAM consortium will be long-lasting working relationships, with partners in the process of identifying and applying for further funding. At the time of consultation (May 2022), two project partners were in the process of identifying funds to continue the research (e.g. Causeway Sensors and UoG), whilst funding applications had already been submitted to HEA and UK sources.
- Ten of the PhD students are staying in the region and will continue to embed their knowledge into the wider ecosystem.
- The partnerships created as a result of NWCAM have built the foundations to apply the NWCAM model (industry-led research challenges and innovation brokerage) to future projects.
- NWCAM has engaged with MATRIX, following the recognition that there was a need to refresh their sector panels.
- Catalyst is working with DCSDC on the City Deal project which focuses on collaboration.

The project partners noted that a positive external factor was C-I's involvement with the City Deal which had served to focus stakeholders on the potential sustainability of the activities within their projects beyond the NWCAM project period. The project partnership outlined that Catalyst has been approached by other stakeholders to explain how the industry-led facilitated model that was implemented to deliver NWCAM worked in practice.

5. ECME - EASTERN CORRIDOR MEDICAL ENGINEERING CENTRE

5.1 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.

5.2 Project Overview

5.2.1 Rationale for the Project

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[47], which will bring with it a higher level of age-related illnesses and injuries. As a consequence, public healthcare 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 focused on cardiology as this was 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 sought 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 remained 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. Heart disease is more than twice as prevalent in NI (8.8%) than in ROI (4.1%) and people from low socio-economic backgrounds were more likely to suffer.

The management of heart disease and related diseases had 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 had led to improved short-term case fatality rates, they resulted in people living longer with heart failure; which has higher resource implications.

Research in Scotland[48] highlighted the rising incidence of heart failure, and the impact that this had on GPs visits and hospitalisation, noting that the expectation was that between 2000 and 2020 there was 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 was clear that the magnitude of the rising costs was significant and a project that enabled this to be more efficiently managed had the potential to represent value for money.

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

Remote patient monitoring, which was the focus of ECME's work packages, can 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 healthcare costs, by up to $36 billion worldwide by 2018 and although this is considerably less than 1% of the total $7 trillion global spend, it offers many opportunities. Much of the savings are derived by reducing hospitalisations and extending independent living for seniors.

5.2.2 Project Partners

ECME represented 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 incorporates the Applied Research for Connected Health Centre (ARCH) and the Insight Centre for Data Analytics (INSIGHT, Prof Brian Caulfield).

The project also incorporated 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 was the Cardiac Research Centre at NI's Southern Trust (ST, Craigavon).

5.2.3 Project Overview, Objectives and Activities

The ECME project involved several key activities, that were captured within seven work packages, with the research and innovation activities grouped into five[49] separate work packages based on an industry-informed challenge. The project also included a communication/dissemination strategy that sought to optimise the potential economic benefits of the envisaged newly developed know-how.

The Project's aims were:

- To implement a cross-border centre of critical mass and excellence that would 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 spinouts and new product development in industry partner businesses;
- To provide a big data structure and database that would 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. The aim was to develop this into an internationally leading doctoral training and innovation centre, with a critical mass that allows global recognition, high-quality leadership development and excellent Industry interactions.

The partnership had previously been highly successful at influencing the EU and global impact within their respective areas. It was anticipated that the ECME project would provide the partnership with the impetus and funding to work collectively to make a step change to where industry and academia were placed in the globally competitive remote patient monitoring market. The various PhD projects and RA

[49] The five research and innovation work packages are as follows: 1. Cardiac Big Data R&I, 2. Smart Wearables founded in Connected Sensor R&I, 3. Rapid Homecare Point of Care Diagnostics R&I, 4. Ambient Assisted Living (AAL) Home-Based Self-Management R&I and 5. Self-Management/ Rehab.

innovation projects that comprised the ECME Centre projects were informed through the partnership's experience and consultation with industry leaders.

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

Whilst the partners already had strong ties with industry, it was anticipated that the programme would address new and deeper relationships. The project partners advise that the project had been co-designed with industry to address market issues and trends/opportunities. The industry partners were core to the project and were 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.

The project's fundamental science base was to 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 was anticipated that these factors would underpin each project as well as sustain the programme's high levels of innovation.

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

To deliver the project activities, seven work plans were developed, as follows:

Table 5.1: 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.
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	

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

Table 5.2: 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.

Table 5.2: 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**	
5. Self-Management/ Rehab	TRL 3	TRL 5	TRL 3	TRL 6	ST, Intelesens, Heartsine, Total Mobile.

It was anticipated that the PhD students would 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 featured 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 would be delivered at a local level. It was also envisaged that the PhD students would learn entrepreneurial skills, helping them to think creatively and explore career paths beyond an academic setting.

The overall project sought to 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 was managed by the clinicians and PhD students were continuously introduced into the clinical environment with some placements possible in their final years.

5.2.4 Anticipated Outcomes and Results

The eligible region had recognised business export excellence within the target market of remote patient diagnostics; and had 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 was envisaged that there would be an enhanced critical mass of expertise that should lead to industry innovation, informed by research and development.

This newly formed ‘ECME Alliance’ sought 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.

In addition, it was anticipated that the ECME Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 81 peer-reviewed journal articles with cross-border authorship.

5.3 Project Expenditure to July 2022

The ECME project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €8,151,717 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €8,362,917.

In June 2021, the SEUPB issued a revised LoO (dated 15th June 2021) which approved a project extension, to 30th June 2022, and a reallocation of the budget between categories.

Further to the above, the Evaluation Team's review of SEUPB's EMS indicates that there has since been another extension to the project end date until the 31st of July 2022 and a further reallocation of the budget between categories, as reflected below. As of mid-July 2022, the project had reported total estimated expenditure of €8,125,466, equivalent to 97% of the total project budget.

Table 5.3: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Estimated Expenditure in July 2022[50]			
		Reported to JS by FLC	Pipeline Expenditure (excluding items deemed ineligible by FLC)	Total Estimated Expenditure	% of the total budget
Staff Costs	2,494,018	1,437,896	1,062,650	2,500,546	100%
Office and Administration Costs	1,506,231	1,067,789	425,787	1,493,576	99%
Travel and Accommodation Costs	73,817	32,758	16,084	48,843	66%
External Expertise and Advice	3,885,989	2,706,361	993,989	3,700,350	95%
Equipment Costs	402,862	322,346	59,805	382,151	95%
Total	**8,362,917**	**5,567,151**	**2,558,315**	**8,125,466**	**97%**

Discussion with the ECME project partnership in April/May 2022 indicated that it was anticipated that there would be a 1-2% underspend at the end of the project period.

[50] Source: SEUPB's EMS 18th July 2022

5.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the ECME project's key achievements 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, the project's ability to contribute to the achievement of the Specific Objective.

5.4.1 Key Activities Undertaken (to May 2022)

The Evaluation Team's review of the ECME project partners' progress reports indicates that key activities undertaken since the second evaluation report (between December 2019 and May 2022) include the following: [51]

Table 5.4: Key Activities

Period	Dates	Key Activities /Points of Note
12	1st December 2019 – 28th February 2020	• The management team prepared to start many of the industrially focused projects. They also commenced planning ECME 2020 as a mid-point conference and networking event designed to bring the healthcare technology community in the region together.
13	1st March 2020 – 31st May 2020	• Some of the project's research moved, where possible/appropriate, towards a focus on the Covid-19 pandemic which sought to ensure that the project was helping to carry out the most impactful research possible whilst meeting the project objectives. • Plans for the industrially focused mini-projects were altered to focus on solutions to the pandemic. • Despite the Covid-19-related disruption, there were several publication successes in this period, some of which were cross-border.
14	1st June 2020 – 31st August 2020	• The PhD researchers continued to work on their PhD projects. • The Covid-19-focused mini projects were launched. • One of the research assistants was promoted within their organisation during this period.
15	1st September 2020 – 30th November 2020	• Project work continued but on a remote basis due to pandemic-related restrictions; • Work to organise the online ECME 202 conference was undertaken.
16	1st December 2020 – 28th February 2021	• An increasing volume of research activity took place in laboratory settings. • The ECME project hosted its first virtual conference which featured 26 presentations, panel discussions and associated publications on a range of project-related topics. • Cross-border publications were developed, with one paper accepted for publication in the Journal of Medical Internet Research (JMIR). • Dundalk Institute of Technology (DkIT) submitted papers to the IEEE EMB Conference and a symposium paper was submitted to the ACBS World Online Conference 2021.
17	1st March 2021 – 31st May 2021	• A joint ECME and Dell Artificial Intelligence (AI) workshop took place with industry partners.

[51] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time (July 2022) of writing. The most recently available collated Project Progress report for the project was for period 21 (March-May 2022) albeit it was in progress and did not detail key achievements. Therefore, key achievements from this period have been taken from individual partner progress reports.

Table 5.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
18	1st June 2021 – 31st August 2021	• During this period, most of the PhD and research assistants returned to their laboratories. • Many of the PhD projects were finished, or were towards the end of their research and were engaged in the production of joint publications. • There was a focus on the non-financial support for industry partners to ensure that this was impactful as possible. • DkIT had two papers accepted for publication in JMIR.
19	1st September 2021 – 30th November 2021	• The team focused on the outstanding PhD projects, building platform technologies and planning further non-financial support for some of the partner companies. • DkIT were engaged in data collection and intervention delivery on the cardiac rehabilitation trial. • A Dublin City University (DCU) ECME supervisor gave an Invited Talk at the European Materials Research Society, Fall Meeting which was also an opportunity to disseminate the ECME group's work on wireless electrochemistry focused on pathogen detection.
20	1st December 2021 – 28th February 2022	• Planning for the project's closing conference and a digital health spring school began. In addition, the project team participated in a trip to the society of computerised cardiology in the US. • The PDRAs continued to work on the various platform technologies. • One UHI student passed their VIVA. • One post-doc published a cross-border systematic review in a special issue of the International Journal of Environmental Research and Public Health. In addition, they had a cross-border abstract selected for presentation at The International Society of Behavioural Nutrition and Physical Activity (ISBNPA) conference in Phoenix, Arizona. • The same post-doc resumed studies using human volunteers to evaluate smart wearable technology and a novel data capture system for the assimilation of data from different platforms. • DkIT had two cross-border publications accepted.
21	1st March 2022 – 31st May 2022 (From Partner Progress Reports)	• The project held its closing conference on 27th May 2022. This was well attended with c.150 attendees from academia, business and the healthcare sector. • Ulster University held a regulatory summer school in May for industry partners to help them navigate the complex process of getting medical devices. • A delegation of SMEs was sent to the International Society for Computerised Electrocardiology (ISCE) conference in Las Vegas. • DkIT completed data collection from their cardiac rehabilitation trial with analysis and reporting underway and the first paper from this work was submitted for peer review in the JMIR Cardiology Journal. • Testing of digital psychology intervention on the CABIE SIMS platform with 9 adults with cardiac disease concluded and analysis commenced. • Presentations were given at various national and international conferences. • A DCU student graduated with their PhD awarded in this period. • One UCD student submitted their thesis in May. • Southern Trust's data analytics platform technology work was completed. • The UHI student that passed their VIVA in the previous period was awarded their PhD.

5.4.2 External Impact Factors

Discussion with the ECME Project Partners indicates that the project encountered several issues during its delivery. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the ECME Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, project partners or direct beneficiaries started working remotely. Some of the project beneficiaries' staff were paced on furlough;
- Some project partners and direct beneficiaries switched focus to begin producing PPE to help address the spread of COVID-19.
- There were limited opportunities to collaborate to produce cross-border publications.
- Some projects were not able to carry out research/testing, due to laboratory facilities having to close and a reduction in access to patients, albeit some researchers were able to undertake aspects of the project remotely;
- The ECME mid-term conference was postponed and ultimately had to be delivered virtually. The ECME 2020 Conference was published in digital and video formats.

Ultimately, as outlined in Section 5.3, to allow the ECME project further scope and time to progress its planned activities, the project received a seven-month extension to the project to 31st July 2022.[52]

During discussion in April/May 2022, the project partnership outlined that covid-19 had a massive impact on the project as it closed laboratories for long periods, stopped access to patients and limited attendance at conferences. It also impacted the ability to undertake collaborative research as in the project partnership's view, collaborative research relies on physical interactions to build relationships, which will impact the project's ability to reach the cross-border publications result indicator target.

In contrast to the above, the project partners also highlighted some positive factors resulting from the Covid-19 pandemic, including for example:

- The ECME project was able to repurpose the Grants to Industry to meet the needs emerging from the COVID-19 pandemic. The project partners were impressed by the quality of the applications, which in their view made the ECME mini-projects much more impactful. The project partnership was particularly thankful for SEUPB allowing them to pivot the project (by offering the COVID projects) which are considered to have been of great help in helping the project meet its targets and keep the team productive;
- In some cases, activity under the Platform Technology Development with Post-Doc Researchers: accelerated. For example, the work on COVID-19 modelling assists in the decision-making process for clinicians in Northern Ireland.
- The move towards digital health care has accelerated as a result of the pandemic.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit resulted in the project facing difficulty securing materials, and as such researchers in Belfast had to go to Dublin to work as it was easier to have materials delivered there as opposed to NI.

[52] To facilitate the completion of the Final Evaluation report within SEUPB's required timeframe, discussions with the project partnership were undertaken during April/May 2022, meaning that the project continued to have circa 3 months before it was anticipated to complete.

Going forward, the project partners highlighted that the NI Protocol could impact similar projects in terms of regulatory approval for medical devices and market access, and also that the ability to apply for future funding may also impact similar cross-border workings going forward.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the ECME project included:

- **Delays in the recruitment of PhD students** to support project delivery - Consultation with the Project's Partners indicates that there were delays in the recruitment of PhD students to support the delivery of the ECME project, which may have arisen since several different projects (including those funded through Priority 1 of the INTERREG VA Programme) were simultaneously seeking to recruit PhD students within the HLS 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 were encountered in non-EU resident PhD students travelling outside their country of research residence. Whilst it was noted that the use of videoconferencing had served to mitigate this issue (at least in part), it did not serve 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 assembled a research team consisting of 'pure' and social scientists. The Partners note that, on occasions, this 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 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 were not 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 were of the view that the project was uniquely positioned to integrate this medium within the project and support businesses that were interested in implementing it within their operations.

5.4.3 Variation to Planned Activities

The project partnership outlined the following specific activities that were originally proposed not implemented, or not implemented in the way or extent that was originally proposed:

- The number of student placements was lower than originally proposed as a result of Covid-19;
- PhD researchers pulled out and were replaced by research assistants;
- The focus/direction of the enterprise funding changed from cardiac health to responding to Covid-19; and
- The project was supposed to hold a mid-term conference in May 2020; however, this was cancelled due to Covid-19, and a virtual conference was held.

5.4.4 *Progress towards the Project's Output Indicators*

As of April/May 2022, the ECME Project Partnership was of the view that it had fully achieved its anticipated (approved) project outputs, with:

- 10 enterprises receiving support (CO01) and non-financial support (CO04);
- 12 enterprises cooperating with research institutions (CO26) and participating in cross-border, transnational or interregional research projects (CO41);
- 12 enterprises receiving grants (CO02) (against the project's original target of 5);
- 103.09 research years (against the project's original target of 95); and
- 5 research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 5.5: Progress towards the Output Targets

Output Code	Description	Programme Target	ECME Target	Progress as of April/ May 2022[53]	Variance against project target
C001	No. of enterprises receiving support	20	**10**	10[54]	-
C002	No. enterprises receiving grants	10	**5**	12[55]	+140%
C004	No. enterprises receiving non-financial support	20	**10**	10	-
C024	No new researchers in supported entities (Total FTEs)	514	**95**	103.09	+9%
C026	No. enterprises cooperating with RIs	10	**10**	12	+20%
C041	No. enterprises participating in cross-border research projects	10	**10**	12	+20%
C042	No. research institutions participating in cross-border research projects	5	**5**	5	-

[53] Source: Discussion with Project Partnership
[54] During discussion the Project Partnership outlined that it had provided support (non-financial and/or financial) to 36 businesses (32 unique), albeit only the top 10 were included to count towards the C001 and CO04 output targets. The level of interaction and support differed by business, for example, training, workshops, expert advice, student placements and access to equipment etc.
[55] Pulse AI, S2ACK Ltd, Advance Engineering, ProAxsis, Anaeko, S3 Connected Health, 42 Genetics, Digital Care Systems, Biopanda Reagents, HeartSine (Stryker), B.Secur and AXIAL-3D

5.4.5 Key Achievements (to May 2022)

Discussion with the project partners indicates that they consider the following to be amongst the ECME project's key achievements (as of May 2022):

- The project created a new cross-border R&I centre within the field of cardiovascular medicine, in particular, focusing on medical-grade wearables and associated remote monitoring systems, which encompassed 6 project partners:
  - UU NIBEC,
  - DCU Biomedical Diagnostics Institute;
  - DkIT Netwell & the Regulated Software Centre;
  - SHSCT Cardiac Research Unit;
  - UCD Insight Centre for Data Analytics; and
  - UHI Department of Diabetes and Cardiovascular Science/Rural Health.
- The delivery of the ECME Doctoral Training Centre which provided PhD researchers with an enhanced experience in several key ways (e.g. training, networking and contact with clinicians and industry from an early stage in their PhD journey) intended to make them future leaders in the healthcare technology sector. The ECME Doctoral Training Centre provided an increased set of skills, both research-related and transferable ones, leading to improved employability and career prospects both in and outside academia (leading in the longer term to more successful careers), and a greater contribution, in the longer term, to the knowledge-based economy and society.
- The project partnership outlined that the researcher year target (of 95 researcher years) for the project was made up of 24 PhD researchers, an overview of the research projects is provided in Appendix VII, and 3 post-graduate researchers, however throughout the project PhD students dropped out, and as the length of time left on the project was insufficient to complete a PhD, the funding was converted (with the support of SEUPB) to support additional PDRAs to further develop the platform technologies.
- As of June 2022, the position of the participant PhD students was as follows:
  - 5 completed PhDs;
  - 5 submitted PhDs;
  - 8 ongoing projects; and
  - 6 withdrawals from the project.
- The project partnership outlined that all researchers took part in a range of training and courses including a tailored course in the area of Lean Start Innovation, which was intended to make them future leaders in the healthcare technology sector. The project partners noted that no spin-out type activity occurred, however, there was an attempted spin-out whereby a student pitched their idea but then discovered it was not viable. Feedback from one PhD was as follows:

> *"I currently work at NVIDIA, which is the world's leading AI platform with a valuation of approximately $750BN. My role is "Global Lead for Life Sciences Alliances". I manage a team of Senior Developer Relations Managers based across the US, Europe and China. My team is responsible for establishing and leading collaborations between NVIDIA and a range of life sciences partners, including several of the world's top 20 pharma, major clinical centres like Mass General and Guy's & St Thomas's NHS Trust, academic centres such as the Broad and Wellcome Sanger Institutes, and national institutions such as the NIH and NHS England. Our work has resulted in breakthroughs in AI for drug design, medical imaging, genomics and medical natural language processing.*
>
> *I also have a regional role as the clinical lead for Europe. In this capacity, I am personally responsible for the scientific project pipeline for Cambridge-1, which is the UK's most powerful supercomputer. The projects we are running on Cambridge-1 include ground-breaking research into brain imaging, novel approaches to drug molecule design, and state-of-the-art applications in next-generation sequencing. I sit on the Technical Design Authority for the London AI platform: among the world's largest clinical AI programmes which has recently seen its first deployment into the London NHS. I also sit on the Monitoring Board for PathLAKE - a major NHS computational pathology (C-Path) programme and one of the largest*

C-Path consortia globally - and the Governance Committee for the King's College London Innovation Scholar's programme. I am also a contributor to DIGITALEUROPE's Executive Council for Health.

The experience and exposure I gained from the ECME programme have been fundamental to my career progression in this field."

In addition, there was a company spin-in into the university linked to the project's research area.

- Whilst all PhD students were to benefit from a final year industry placement, the project partnership outlined that due to the impact of Covid-19, only 6 students were able to complete a placement. An overview of the placement details and duration of each placement is provided below.

Table 5.6: PhD Students Industry Placements

No.	Company	Duration	Placement details
1	NHS	6 months	Frontline NHS Nurse working on COVID-19.
2	Enfer Group	5 months	COVID-19 PCR testing labs at Enfer labs in Naas, Kildare.
3	PulseAI	10 months	This project involved the development of an AI-based algorithm for accurate estimation of cuffless blood pressure from physiological signals including the electrocardiogram and photoplethysmography signals.
4	iCURE Programme	4 months	Market research into wearable, personalised sodium tracker.
5	NHS	6 months	Part of the Government's Specialist Modelling Response Expert Group in Northern Ireland.
6	Trimvale Engineering	1 month	Helped the company to develop a winch and ramp controller to assist disabled individuals in mobility vehicles.

- From the academic and clinical institutes' perspectives, it was anticipated that ECME would provide a big data structure and database that would enable future joint working amongst partners to enrich the validity of health and life science solutions developed, however, the project partnership outlined that partners concluded that the usefulness of a big data structure and database would be limited, and instead research was refocussed onto Covid-19 data.
- As a medical research centre, ECME and its staff across the UK, found themselves playing a pivotal role in the national response to the pandemic. The staff were on the front line directly with patients and answered the call to join the UK Government's Rapid Test Consortium. The staff assisted with developing antibody tests for COVID-19 and were involved in the modelling of various aspects of COVID's spread and impact. In addition, the project took a proactive approach against covid-19 with the delivery of 9 mini projects. The project requested to change the focus of the grants from cardio-technology to covid-19 in response to the pandemic. The ECME Programme Director noted:

  "We were very impressed by the response to the ECME COVID-19 Call both in terms of the number of applications received but also the readiness of the applicant companies to respond swiftly to the COVID-19 pandemic."

- The project partnership outlined that several platform technologies[56] were developed as part of ECME, including:

  - The Assessment of Cardiovascular Risk in The Eye Using a Slit Camera;
  - The user experience of home-based AbC-19 SARS-CoV-2 antibody rapid lateral flow immunoassay test;
  - The Use of Digital Technology to Deliver an Acceptance and Commitment Therapy Intervention for the Improvement of Self-management Behaviours and Psychological Flexibility in Adults with Cardiac Disease;
  - Delivering Cardiac Rehabilitation Exercise Virtually Using a Digital Health Platform;
  - The Use of Amninis CellStream for the Development of Knovel Diagnostic Tools - The platform has been successfully deployed for several projects, including the ECME project that analysed dysfunctional endothelium-derived EVs following exposure of endothelial cells to hyperglycaemic conditions.
  - A digital platform to allow GPs and clinicians to refer patients to the Cardiology Service within a Health and Social Care Trust.

5.4.6 Progress toward the Project's Objectives

Table 5.7 provides a summary of the progress that has been made by the project against its stated objectives.

Table 5.7: Project-Specific Objectives[57]

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 large degree	ECME has nearly completed the majority of the projects and had delivered many high-quality papers and other outputs.
To undertake excellent research (commencing at TRL levels of between 1 and 3), through the creation of 24 PhD studentships	To a large degree	Both postdocs and PhDs have continued to carry out low TRL research throughout this period and are on track to meet the output indicators in this area.
To engage with ten industry partners at TRL levels of between 2 and 6.	To a large degree	ECME's industrial partners have completed the majority of the COVID-19 mini-projects and are now delivering the remainder of the non-financial support element of the project.

5.4.7 Progress towards the Project's Result Indicator Targets

It was anticipated that the ECME Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 81 peer-reviewed journal articles with cross-border authorship.

The project partnership noted that as of March 2022, the project had published 79 peer-reviewed journal articles, 49 of which had cross-border authorship. The project partnership highlighted that they might not achieve their target due to the limited opportunities to collaborate as a result of the onset of Covid-19 as meetings were not possible in the same way they were pre-pandemic, and they were unable to attend conferences.

[56] The project partnership highlighted that the details associated with these platform technologies are commercially sensitive.
[57] Source: Project Progress Report 20 – 'Project Specific Objectives'. This was the most recently available collated project progress report.

Table 5.8: Progress towards the Result Indicator Targets		
Category	**ECME Target**	**Actual (at March 2022[58])**
Joint cross-border papers published	81	49[59]

Appendix VIII provides a list of the cross-border publications produced.

5.5 Best Practice and Learning

This section considers whether the ECME project has resulted in any areas of best practice and learning.

Key examples of best practices 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 include:

  – Joint training sessions focusing on developing transferable and 'real-world' skills such as 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 contributed to establishing a 'bottom-up' approach to the research activities and support the creation of potential 'leaders of the future'; and

- Before the Covid-19 pandemic, rotation of quarterly progress meetings at each of the Project's Partner's respective institutions to coincide with other events/conferences to stimulate a joint sense of project ownership (rather than the project being UU-centric) and greater levels of transnational interaction

5.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

ECME's management team at Ulster worked 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 delivering on the Marie Curie principles for research.

ECME's project partners also note that it has undertaken several informal meetings with the other INTERREG VA project managers.

The ECME project partners suggest that they implemented several activities to enhance the effectiveness of cross-border collaboration concerning the specific objectives and new ways of working that would otherwise not be possible in the absence of INTERREG VA. These include:

[58] Source: Discussion with the Project Partnership in April/May 2022.
[59] However, the total number of publications is 79.

Joint Development	The design of the project was agreed upon 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 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 represented the culmination of a sustained shared vision by world-renowned scientists; whilst the inclusion of UHI represented a completely new working relationship for all partners. At a strategic level, a Project Management Board was set up to oversee the work packages. It met every quarter in rotating venues (pre-covid) amongst the partners. Membership of this project board was drawn from representation from all partners, as well as two industry representatives and Research Office representatives. An Advisory Board met annually to review and internationally benchmark the project to ensure that it was being suitably and unbiasedly implemented. At an operational level, PhD students and RAs were appointed within the five project partners. The identified work packages were selected based on expert input, with the firm belief that these projects would 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 had a PhD supervision team and in all cases, a cross-border advisor has been appointed to the panel. Areas of expertise were matched to complement each other and provide the student with exchange opportunities. From the perspective of the PhD students, the intention was that there would be joint supervision across institutions and/or clinical partners. Industry placements were also encouraged within companies where appropriate. Joint publishing in world-class journals and keynotes at International Conferences; Joint- exchanges; Joint Training (Specialist, academic and commercial); Joint Grant Writing; Equipment access etc., were all 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[60], they have achieved:

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 practices 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

[60] 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.

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 saw an industry problem informing the PhD titles and involving live feedback and tailoring of research focus is new for the project partners.

5.7 Impact on Business and Industry

This section considers the impact of the ECME project on businesses and industry within the eligible region.

The project provided financial support to 12 businesses in the form of grants to 9 businesses and support to 3 businesses to attend the ISCE conference held in Las Vegas in April 2022.

For the grant element, the project ran a bid competition and supported 9 mini covid projects. The projects ranged from PPE manufacture to AI-powered (Artificial Intelligence) ECG wearables to new diagnostics test kits., with an overview of each provided below.

Table 5.9: Overview of the Covid-19 Mini Projects

Business	Project
s2ack Ltd	*System for Remote Monitoring of ECG/SpO2/Respiration during Covid-19 Crises* - s2ack's mini project was to design a remote patient monitoring system for ECG, SpO2 and respiration.
Anaeko	*RELAX Restriction Examination & Local Analysis eXchange Software Project* - Anaeko's mini project was to build a health datahub and geospatial dashboard, leveraging open data to correlate geospatial health information. The platform was anticipated to optimise ultra-local logistics and community care for high-risk groups when relaxing Covid-10 restrictions and beyond.
42 Genetics	*Federated Data Consolidation Software Project* - 42 Genetics' mini project was to develop software that reduces the time and footprint needed for population-based genomic analysis related to rare diseases and viral infections, including Covid-19.
Pulse AI	*Development of an artificial-intelligence-powered ECG patch to monitor COVID-19 patients for early signs of drug-induced sudden cardiac death* - Pulse AI's mini project was to develop an Artificial Intelligence (AI) powered ECG patch to monitor Covid-19 patients for early signs of drug-induced sudden cardiac risk.
Biopanda Diagnostics	*Development of a fluorescence-based rapid test kit for the detection of IgM/IgG antibodies against SARS-CoV-2* - Biopanda Diagnostics' mini project was anticipated to develop a fluorescence-based rapid test kit for the detection of IgM/IgG antigens against SARS-Cov-2.
Digital Care Systems	*Chest pain diagnosis ASSIST* - ASSIST (Automation to Support Self-assessment of Illness Symptoms for Triage) was anticipated to support an asynchronous and remote approach to the assessment of non-emergency chest pain symptoms.
Ad-Vance Engineering	*Vision PPE single-use face shield upgrade* - Ad-Vance Engineering's mini project was to design a PPE face shield and manufacture 10,000 units per day for the NHS, HSE and industrial users.
ProAxsis	*Cathepsin G Assay: A novel biomarker of poorer outcomes for COVID-19 patients* - ProAxsis mini project was to develop a fully validated version of an activity-based laboratory assay for Cathepsin G, ready for CE Mark registration and future adaption to a point of care format.
S3 Connected Health	*ACORRD for COVID-19 Northern Health and Social Care Trust Pilot* - S3 Connected Health's mini project known as ACCORD was a digital clinical support service for Health Care Professionals (HCPs) who were managing Covid-19 patients in a hospital. It was designed to help HCPs organise, triage, monitor and treat patients with the virus.

The project partnership noted that those involved in the mini-projects were already seeing the impact in new products, new markets, increased revenues and additional research funding The project partners provided the following highlights from the mini-projects:

- 42 Genetics Ltd were able to use their grant as a springboard into further research funding totalling £700K from Innovate UK.
- Anaeko Ltd secured new contracts worth £75,000 and submitted bids for business worth £250,000.
- ProAxsis Ltd used its ECME funding to develop an assay for the detection of the biomarker Cathepsin in COVID-19 patients. ProAxsis Ltd was also part of one of the consortium from Northern Ireland to be selected for the next stage of the UKRI's Strength in Places Fund (SIPF) and was awarded seed-corn funding of up to £50,000.
- Advance Engineering was able to rapidly bring a range of PPE visors to market, supply facilities across the UK and explore export opportunities to Canada. During the lockdown period, all of the business' resources were utilised in the design and manufacture of these tools, this secured employment with no employees being furloughed during this time. The business developed a new TPE headband which was being injection moulded. This is the only moulded headband on the market and it has also achieved CE Approval.
- S2ACK were able to expedite the design and development phases for their NeedlePoint system as a result of the ECME project's support. Although the business has not yet generated a direct impact in revenue, the business plans to continue refining the system to the point that it could achieve certification for use on the human body.
- Pulse AI completed its project by delivering a patch-based ECG device which can be used with an Android smartphone to automatically monitor the QTc interval from the ECG remotely, allowing for continuous monitoring of COVID-19 patients for the early signs of drug-induced sudden cardiac risk. The project allowed Pulse AI to rapidly develop its remote monitoring platform around AI-ECG algorithms, which has increased the company's profile both locally and internationally and has attracted clinical partners and potential customers from the US and Europe.
- Biopanda Reagents used the Mini Projects funding to develop an extension to their line of LFA rapid test kits for COVID-19 antigens. Their new device uses gold nanoshells instead of colloidal gold to improve the detection limit for the S protein. It was undergoing clinical trials. Biopanda Reagents COVID-19 Antigen Lateral Flow test passed the UK Government's validation process with high sensitivity and specificity.

In addition to the financial support, the project provided non-financial support to 36 businesses (32 unique). The type of non-financial support varied by business, but included training courses/workshops (e.g. in Artificial Intelligence, Machine Learning, Big Data Management, Communications and User Centric Design)[61], access to expert advice and equipment.

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

- Increase 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.

[61] For example, ECME held an online training event for local companies in partnership with Dell and NVIDIA. The training was designed as a deep-dive into some of the fundamentals of Artificial Intelligence, including Machine Learning, Deep Learning and deployment.

5.8 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 Cohesion Policy and EU 2020 objectives;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

5.8.1 EU Cohesion Policy and EU2020 Objectives

The ECME project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and enhancing the competitiveness of SMEs.

The ECME project has also helped to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

5.8.2 The Horizontal Principles

The ECME project has contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

<table>
<tr>
<td>Sustainable Development</td>
<td>According to the project partners, the project was developed with a view to sustainable and positive growth of the connected health sector in the eligible region. It was anticipated that the proposed research, which would be fully available on Open Access at the Gold Level, would inspire the world with innovative technologies, products and designs —to enrich people's lives while contributing to a socially responsible future.

According to the project partners, the 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 worked towards a positive impact as moving healthcare management to the home sought to save on travel and hospital heating costs.

The project also used zoom meetings (even before Covid-19) where possible to reduce the amount of travel required by project staff and also encourage lift sharing and sustainable transport.</td>
</tr>
</table>

Equal opportunities and non-discrimination	Ulster University has an Equality Diversity and Inclusion Strategy 2019-2022 which sets out the University's commitment to and proposals for fulfilling statutory obligations concerning Section 75 and Schedule 9 of the NI Act (1998). Ulster University, as the lead partner, sought to ensure that each of the partners working on the project provided equality of opportunity during the management and implementation of the project. The project partners cited an example of this whereby they 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 the lead partner, sought to ensure that each of the partners working on the project adhered to the principles of the Athena Swan Charter[62] across the partnership. Ulster received a bronze award[63] in the Athena Swan Charter in 2014, whilst UHI received a bronze award in 2017. All Irish Universities and third-level institutions announced that they were working to address gender imbalances in the higher education sector through the extension of the Athena SWAN Charter to Ireland.

5.8.3 Contribution to Other Strategies

The ECME project's activities and objectives align with several regional and national action plans and strategies, including:

Table 5.10: Project's alignment with regional and national action plans and strategies

Subject	Relevant Documentation and Alignment
Economic	• The ECME Centre Project aligned with the strategic objectives of the Northern Ireland Economic Strategy that set out the NI Executive's plan to grow a prosperous economy by stimulating innovation by 2020 and it also described how R&D would position NI as a global innovation leader to build a sustainable economy. • NI's Draft PfG 2016-2021 also aimed to modernise health and social care. • ROI's NRP 2016: which recognised Health/labour markets as a source of economic growth and health outcomes. • Similarly, ECME was consistent with Scotland's Economic Strategy 2015 which sought to foster a culture of innovation by supporting high-impact, world-class research in Scotland's universities and improving levels of commercialisation of academic research.
Research and Innovation	• NI's MATRIX Panel highlighted the industry's demand for PhD-trained students. • NI's Healthcare Strategy for R&D (2016) also provided a focus on innovation and R&D. • ROI's Innovation 2020 highlighted 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" recognised 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 highlighted the need for ICT and digital tech to revolutionise healthcare to improve patient and economic benefits. In addition, Quality 2020 referred 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 recognised the need to maximise the use of tech and incentivise innovation. • ROI's 'Future Health' and 'Healthy Ireland' emphasised chronic illness prevention and shifting from episodic care to outcome-based care. • Within Scotland, key documents included "Achieving Sustainable Quality in Scotland's Healthcare" and "Renewing Scotland's Public Services". These focused on prevention, anticipation and supported self-management. Also developing information technology and business processes to gain from investment in eHealth.

[62] This Charter recognizes and celebrates good employment practice for women working in science, technology, engineering and maths (STEM) in higher education and research

[63] The Bronze Award submission includes a three-year Action Plan aimed at supporting and developing the careers of women in STEM at Ulster

Table 5.10: Project's alignment with regional and national action plans and strategies	
Subject	**Relevant Documentation and Alignment**
E-health	• In NI, the E-Health and Social Care Strategy was 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' noted national healthcare ICT spending would be "re-aligned" so that it reached the "EU average of 2-3%" from the current 0.85%. • Scotland's eHealth Strategy identified several 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 included research into the prevention, treatment, rehabilitation and care. Aligned with the priorities, NICHS was funding research for the study of people and populations. • ROI's Changing Cardiovascular Health highlighted a potential epidemic of heart failure over the next 10 years. There was a call for care-led community teams to improve patient outcomes and release hospital capacity. • Scotland's Heart Disease Improvement Plan set out an ambitious person-centred plan to deliver clinically effective and safe HSC. Inter alia, the plan prioritised the prevention of CVD and heart failure.

In summary, the Evaluation Team is of the view that the ECME project has contributed to a range of strategic imperatives that existed across the eligible region.

5.9 Barriers to Cross-Border Co-operation

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

The ECME project partners note that an issue that they have encountered had been the differing policies in place concerning PhD training. To address this, they allowed flexibility to ensure that the training procedures employed met both institutional and project requirements. No further barriers were cited by the Project Partners.

5.10 Potential Legacy Impacts

The ECME Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- The ECME Project Partners consider that the ECME project has been a fundamental partner in the development of one of the Belfast Regional City Deal projects, the Centre for Digital Healthcare Technology (CDHT), through building capacity and a track record for project delivery at a larger scale. In addition, the partnerships developed with industry through ECME have also rolled into the BRCD project.
- In addition to the potential city deal funding, project partners are seeking further funding opportunities to continue and expand on the research undertaken as part of the ECME project. For example, at UU the plan is to double the level of research in digital health, for which they are seeking research funding.
- ECME staff regularly briefed the government on policy and some staff have been involved in national initiatives around COVID including on the NHS front line and through large-scale COVID data analysis projects. In addition one of the research projects at the Southern Trust indicated that the UK health service could save up to £50m annually on the cost of angiograms to diagnose coronary artery disease.

6. CPM - CENTRE FOR PERSONALISED MEDICINE

6.1 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.

6.2 Project Overview

6.2.1 Rationale for the Project

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 was recognised as a key priority internationally. While the promises of personalised medicine were only beginning to be realised in certain areas of cancer medicine, in particular, other disease areas had 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 aimed to create the often-cited highly sought-after ethos and environment needed if personalised medicine was to be adopted in the partner hospitals and in five disease areas (research clusters) that had not yet engaged the personalised medicine discipline.

The five cluster areas were considered to be areas associated with significant clinical need[64] and commercial potential and would 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 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.

[64] As the five disease areas were associated with significant morbidity and mortality which were of national/international importance, but which posed particular challenges within the ER, especially the NW of Ireland and Western Scotland (each with its different care systems).

6.2.2 Project Partners

The CPM project partners considered that the major strength of the project resided in the expertise of the assembled a highly complementary multidisciplinary team of clinicians, academic researchers and enterprises. In total, the project had 12 project partners, with Ulster University as the Lead Partner[65]. The other partners were:

1. Western Health and Social Care Trust (WHSCT); 2. Letterkenny University Hospital (LUH), 3. Letterkenny Institute of Technology (LyIT); 4. University of Highlands and Islands (UHI); 5. NHS Highlands Scotland (NHSH); 6. Randox Laboratories Ltd (Randox),	7. United Health Group/ Optum Operations (Ireland) Limited, 8. Clinishare Ltd/Voscuris; 9. Healthcare Analytics Ltd 10. Northern Ireland Clinical Research Services (NICRS) and 11. National Universities of Ireland Galway (NUIG).

Each of the partners was based in the Eligible Region except for NUIG, which had been introduced for their Health Economic and dementia-specific expertise.

6.2.3 Project Overview, Objectives and Activities

The CPM project sought to create a cross-border (CB) supercluster of critical mass which would strengthen the CB economy by increasing industry-relevant HLS R&I capability particularly relating to personalised medicine in five disease areas (clusters), as follows:

- RC 1 Primary coronary intervention (PCI) in myocardial infarction (heart disease)
- RC 2 Emergency surgery
- RC 3 Acute kidney injury (AKI)
- RC 4 Unscheduled care in diabetes
- RC 5 Diagnostic accuracy in dementia.

Each RC carried out research to develop improved clinical care pathways leading to new products and services to address present market failures. The proximity of two trans-jurisdictional hospital systems with a link to a third provided an ideal opportunity for research and comparative studies.

To this end, CPM's five Research Clusters (RCs) utilised the methods and technologies from personalised medicine and applied them as follows:

[65] 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).

Table 6.1: 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 were: • To improve the clinical decision-making within the cardiology department and associated patient journeys, 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 had 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 was critical so that those with myocardial infarction [heart attack] could be referred for immediate coronary artery stenting [primary coronary intervention - PCI)]. Altnagelvin provided a 24/7 PCI service for the west of N. Ireland and Donegal. Raigmore Hospital [NHSH] provided a similar service to the Highlands and Islands. Although a patient triage pathway was in place, WHSCT research shows that although highly sensitive, it had only 30% specificity meaning that large numbers of patients were 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 to inform the development of improved patient care pathways. This RC sought to build on the internationally recognised expertise of the LUH emergency surgical team to develop key performance indicators and a comprehensive clinical database. It identified 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 were reducing time to definitive care, optimising diagnosis with the 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 was the most common urgent surgical procedure, with a UK mortality rate of ~15% with wide variation between units. It was a particular challenge outside major centres due to smaller surgical teams and greater reliance on locum/agency staff. Assessment of clinical performance was difficult as it must take into account case mix and patient co-morbidities and was hampered by the lack of validated key performance indicators and data collection and display.

Table 6.1: 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 sought to 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 involved 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 helped 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 aimed 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 was a major challenge in acute hospital care – UK research indicated that 16% of acute adult admissions develop AKI which was 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, NHSH, LUH, C-TRIC	RC 4: This RC sought to research and develop enhanced patient self-management and community clinician management care pathways beyond state-of-the-art. It improved 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 the ambulance services or telemedicine.	Unscheduled care episodes in diabetes were a problem in the North West; at any time 14-22% of WHSCT hospital inpatients had 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 was 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 sought to 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 was realised via the generation of algorithms based on neuropsychological test results, and 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, was undertaken 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 was a global healthcare challenge. There was regional variation in prevalence and disparity in diagnosis rates throughout various health trusts. Prevalence was higher in rural Ireland due to the older age profile of the population. Timely and accurate diagnosis was important for the individual, and family members and for current and novel emerging treatment choices.

The CPM project brought 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].

The CPM project identified the project's specific objectives (per progress reports) as being to achieve the following:

1. 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); and
3. By 1st April 2017, commence work plans with all selected existing staff allocated to the project.

The suggested immediate objectives of the project were 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.

It was envisaged that 5 enterprises would 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 had 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 could be investigated as part of the project for suitability in contributing to clinical decision making in the Research Clusters, it was anticipated that this would have a very positive value for the enterprise in that ultimately it could contribute to the validation of such product(s) in subsequent sales and marketing;
c) **Co-supervision of PhD student(s)** –The project's RC objectives were anticipated to be delivered in large part by the outputs of PhD students (and/or a Research Associate/s) both of which would be frequently co-supervised (and/or advised) by a multidisciplinary team of academics, clinicians and business representatives. Thus, by engaging in this project, it was envisaged that the enterprises would gain extremely valuable expert advice at a very high level that would 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 an RC patient care pathway as articulated in the conceptual framework). In addition, each enterprise needed a skilled workforce, and it was anticipated that their engagement in this project would enable the enterprise to give input that would inform the generic skills developed and included as a part of the PhD student training programme. Ultimately, it was envisaged that the enterprise would 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) were a part of the expected output of each RC. If an enterprise was 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 of the paper. Such recognition had a potentially very positive impact on the reputation of an enterprise and gave them a much greater profile (assuming that the result reported was a positive outcome). This may also have conferred more international credibility to the enterprise(s) involved and would ensure that their product(s) (if used in the study for example) had 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** could 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.

To deliver the project activities, eleven work plans were developed, as follows:

Table 6.2: 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

6.2.4 Anticipated Outcomes and Results

It was anticipated that the CPM project would dramatically enhance regional capability while serving as a magnet for regional and FDI industries to create innovative products and new optimised care pathway tools in priority disease areas for patients and commercial benefit.

In addition, it was anticipated that the CPM Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 13 peer-reviewed journal articles with cross-border authorship.

6.3 Project Expenditure to July 2022

The CPM project received a Letter of Offer (dated 26th June 2017) offering a grant of up to a maximum of €8,628,985 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €9,424,927.

In June 2021, the SEUPB issued a revised LoO (dated 29th June 2021) which approved a project extension, to 30th June 2022, and the reallocation of the budget between categories.

Further to the above, the Evaluation Team's review of SEUPB's EMS indicates that there has since been a further reallocation of the budget between categories, as reflected below. As of July 2022, the project reported total actual expenditure of €8,155,296 equivalent to 87% of the total project budget, however, whilst the project was considered to have been completed at the end of June 2022, this may not reflect the final expenditure position due to the timing of submission and verification of final claims.

Table 6.3: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Total Actual Expenditure[66]	% of the total budget
Staff Costs	4,984,938	4,568,494	92%
Office and Administration Costs	1,818,165	1,584,302	87%
Travel and Accommodation Costs	97,886	43,400	44%
External Expertise and Services	1,581,922	1,435,197	91%
Equipment Costs	942,017	523,903	56%
Total	**9,424,927**	**8,155,296**	**87%**

During discussion (in April/May 2022), the project lead highlighted that there was a potential underspend of c. €400k due to COVID-19 and procurement issues. In addition, the project lead noted a c.€500k underspend by industry partners. However, this underspend was described as a 'false' underspend as these partners funded themselves and the underspend was down to a failure of SEUPB's EMS budget monitoring.

[66] Source: SEUPB's EMS 18th July 2022

6.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the CPM project's key achievements 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, the project's ability to contribute to the achievement of the Specific Objective.

6.4.1 Key Activities Undertaken (to June 2022)

The Evaluation Team's review of the CPM project partners' progress reports indicates that key activities undertaken since the second evaluation report (between April 2020 and June 2022[67]) include the following:

Table 6.4: Key Activities

Period	Dates	Key Activities/Points of Note
13	1st April 2020 – 30th June 2020	• During this period, there was a focus on identifying the impact of Covid-19 and developing/implementing contingency plans to reduce its impact on the project. • Cluster 1 (Emergency Surgery) proposed a Laparotomy Study, examining different cytokine markers at different points of time in the care pathway. • Wet lab work was undertaken on a rotational basis, meaning work commenced on sample storage and preparation for Olink protonomic analyses. • Patient recruitment had not started for vulnerable patients. However, most of the research clusters developed 'workarounds' using existing databases (in circumstances where they were short of participant samples). On an overall basis, the project partners considered that this worked well, and no major delays were faced.
14	1st July 2020 – 30th September 2020	• The Western Health and Social Care Trust (WHSCT) worked to optimise an RNA extraction and a Covid-19 genetic test in the hospital labs. Various genetic Covid-19 markers were tested for sensitivity and specificity. • Electronic case reporting data capture was fully operational. • Clinical care pathways were developed for RUQ/Cholecystitis and RIF pain/appendicitis and discussions took place with hospital stakeholders regarding implementation. • Several papers and presentations were produced by the cardiovascular research cluster PhD students. • Several papers were submitted or were under review from the diabetes research cluster in addition to several conference submissions.
15	1st October 2020 – 31st December 2020	• The Letterkenny University Hospital Emergency General Surgery Inaugural Report was launched (virtually). A press release in Donegal Daily and an interview with Highland Radio coincided with the launch. • Two abstracts were accepted under the Point of Care Work Package for the Scientific Meeting of the UK Association for Clinical Biochemistry and Laboratory Medicine, which was due to take place virtually in April 2021. • Covid-19-related work was carried out under the Point of Care Work Package. • Ulster University (UU) staff provided NHS staff training relating to Covid-19 genetic testing. In addition, UU and WHSCT staff completed their second NI seroprevalence study, which assessed antibody prevalence in NI. • Five papers were accepted or were under review by the Percutaneous Coronary Intervention (PCI) in Myocardial Infarction Work Package.

[67] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time of writing (July 2022).

Table 6.4: Key Activities		
Period	**Dates**	**Key Activities/Points of Note**
		• Four papers were published virtually during this period. • Four cross-border authored journal papers relating to dementia were published or accepted for publication during the period.
16	1st January 2021 – 31st March 2021	• Covid-19-related work in this period included the measurement of antibodies in a prospective COVID-19 cohort of 500 participants as part of the Covid Response study (COVRES) within the Western Trust. The antibody testing was completed, and the results were finalised and sent to the COVRES study team. • All data from Randox had been analysed by one of the research assistants and a PhD student. • A total of 18 papers/conference presentations were submitted in this period, many of which were under review or undergoing amendments.
17	1st April 2021 – 30th June 2021	• The Acute Kidney Injury (AKI) research cluster completed an analysis of Olink data. • Plasma and urine samples were sent to Randox for biomarker measurement. The overall total of plasma samples sent to Randox throughout the project by the end of this period was 279. • Recruitment of occlusive MI patients was nearing completion with 141 of 150 targeted samples collected. • Recruitment and data collection for the study "Quality of Life and Resource Utilisation on the Cholecystectomy Waiting List" was ongoing and preliminary data analysis began. • The first (virtual) Deep Dementia Phenotyping (DEMON) Northern Ireland Research Symposium was organised and delivered in June 2021. • 7 papers from the Dementia research cluster and 5 papers from the diabetes research cluster were under review. • There were 3 publications from the emergency surgery research cluster.
18	1st July 2021 – 30th September 2021	• The AKI research cluster completed its biomarker work. Within this cluster, analysis began on the effects that a specific treatment has on protein expression in addition to the effects that other patient characteristics such as BMI, age and gender have on this. • The cardiovascular research cluster completed patient recruitment and plasma samples were sent to Olink for protein analysis. • The Dementia cluster completed recruitment and was preparing samples for Olink protein analysis to validate their analyses. • Data collection was completed for two diabetes PhD researchers and a Diabetes Covid Experiences Study was submitted to Diabetes Research and Clinical Practice. • Another PhD researcher developed two novel user-friendly apps for streamlining and redesigning Alzheimer's disease assessments, incorporating cost-benefit computations within the machine learning algorithm. Healthcare Analytics expressed strong interest in this work during a meeting with the project in September.
19	1st October 2021 – 31st December 2021	• In 2021 there was a total of 16 papers published and 5 accepted and in print and in December 2021, 7 further papers were under review in academic journals. • Six students had completed their PhDs at this point. • The second annual Emergency Surgery report (EMERGE) was completed. • Randox and Olink completed their analysis for the cardiovascular and AKI studies, allowing for the analysis of large-scale proteomic data and potential novel biomarkers for chronic kidney disease (CKD) progression to be identified. • The dementia research cluster identified novel endocannabinoid and proteomic biomarkers of mild cognitive impairment and dementia. • A PhD student identified a major limitation of the current use of electrocardiograms in diagnosing cardiovascular disease and identified that it was electrode lead misplacement that was responsible for this. This work

Table 6.4: Key Activities		
Period	**Dates**	**Key Activities/Points of Note**
		was selected to be indexed as an evidence document with the National Institute for Health and Care Excellence (NICE). • Another PhD student identified through a retrospective clinical review that despite initial contact with the cardiac unit, the vast majority of patients who have a heart attack are not initially identified as such and therefore are not admitted to a cardiology bed. This leads to additional work and a delay in definitive treatment due to other teams becoming involved and moving across multiple wards.
20	1st January 2022 – 31st March 2022	• The CPM project closing event was held on 23 and 24 March. • The programme manager and the administrator continued to complete outstanding reports and financial tasks during this period.
21	1st April 2022 – 30th June 2022	• Ulster University employed two staff to complete claims for the lead partner and to close out the grant.

6.4.2 External Impact Factors

The Project Partners advise that the project encountered several issues in the delivery of the CPM project. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the CPM Project Partnership during September 2020 as part of the Interim Evaluation report and further discussion in April/May 2022 identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, project partners or direct beneficiaries started working remotely or were furloughed during this period.
- There was also additional work required on samples already collected to ensure that they had not been impacted by COVID.
- Some activities were refocused to support efforts to curtail COVID-19. For example, under the Biomarker, Acute Kidney and Point of Care Testing Work Packages, Coral Lapsley (Research Associate, Biomarkers WP), David Porter (Research Associate, PoC Testing WP) and Andrew English (Research Associate, Acute Kidney WP) completed training on lab equipment (ELISA) at C-TRIC CATII labs and began working in the lab. The purpose of this work was to test plasma samples already collected by the Trusts for SARS-CoV-2-reactive antibodies. They then analysed SARS-CoV-2- antibodies in blood samples to estimate the seroprevalence of COVID-19 in Trusts. This is a Northern Ireland-specific seroprevalence study to help define previous exposure. As the CPM project involved the recruitment of patients in the WHSCT, this study allowed for the determination of exposure across NI and specifically the WHSCT which is of vital importance for data already collected and any data that may be collected in the future.
- Patient recruitment did not reach the expected numbers, so whilst research work demonstrates a reduction in the number of diabetic patients going to a hospital, the numbers are not significant enough.
- Randox was unwilling to submit costs for blood analysis for AKI RC. Due to the number of samples being collected and the likelihood of sufficient samples not being collected, it was not efficient to put the analysers (equipment) into the partner organisations as originally thought, albeit the data was analysed at Randox premises instead.
- In some situations, there was an increased workload for researchers as the pandemic was relevant to the project. Also, a doctor doing a PhD had to be redirected away from the CPM project to clinical work.

Ultimately, as outlined in Section 6.3, to allow the CPM project further scope and time to progress its planned activities, the project received a six-month extension to the project to 30th June 2022.

The project partnership also highlighted two particular contributions of CPM staff to the COVID effort at a national level that aligned with the work of the CPM generally:

- A Research Associate in Data Analytics collaborated with UU academics to develop a pilot contact tracing system for the Public Health Agency (PHA). The system was demonstrated to a consultant in health protection at the PHA and they are now trialling the system on their infrastructure. The research associate is currently providing technical advice regarding setting up the infrastructure of the PHA and working to tailor the system for bespoke Northern Ireland mapping and reporting applications. For example, plotting spot maps of confirmed COVID-19 outbreaks in NI, including data such as care home locations and NHS trust boundaries.
- UU CPM staff are assisting with the COVID Dashboard for Northern Ireland, which provides a breakdown of COVID deaths, cases etc. daily. They are working closely with the Department of Health and a CPM staff member sits on the Modelling Group at the Department level. UU staff will work with LYIT to see if similar data can be got from RoI for comparability across regions.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit impacted the Diabetes RC in terms of requirements to organise GDPR processes which delayed access to LUH's data.

Other Factors

Other specific issues cited by the Project partners include:

- **Differing rules and governance -** Difficulty was encountered whilst implementing the project on a cross-border basis when navigating the different rules and governance (including gaining necessary ethical approvals) associated with research. In addition, the absence of a named project lead in LUH delayed project progress.

- **Lack of communication and cross-project interworking** - Whilst noting that quarterly meetings were held and 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 and if the level of interworking between the research clusters was enhanced it would have supported greater levels of knowledge transfer.

- **Cyber-attacks** - Two project partners experienced cyber-attacks, one in Scotland and the other in Letterkenny, which caused minor delays as the cyber-attack closed the systems and stopped the project from accessing data, albeit for a short time.

6.4.3 Variation to Planned Activities

The project partnership outlined that the following activities that were originally proposed were not implemented, or not implemented in the way or extent that was originally proposed:

- The level of samples collected by the RCs was lower than expected. Randox received 546 patient samples out of an expected 2,000.
- Randox's equipment was not installed on hospital sites as planned, as it was agreed that this was not effective or efficient given the level of samples, and instead Randox completed sample analysis at their premises.
- An Advisory Board was not established as envisaged. In terms of governance, it was envisaged that there would be a Project Board, Steering Committee and Advisory Board. However, a decision was made at the outset by the Steering Committee that there was no added benefit of an Advisory Board.

6.4.4 *Progress towards the Project's Output Indicators*

As of April 2022, the CPM Project Partnership was of the view that it had fully achieved its anticipated (approved) project outputs, with:

- 5 enterprises receiving support (CO01) and non-financial support (CO04), cooperating with research institutions (CO26) and participating in cross-border, transnational or interregional research projects (CO41);
- 3 enterprises receiving grants (CO02);
- 86.7 research years (against the project's original target of 89.5); and
- 4 research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 6.5: Extent of Achievement of Project Output Indicators Targets

Output Code	Description	Programme Target	CPM Target	Actual as of April 2022[68]	Variance Against Project Target (%)
CO01	Number of enterprises receiving support	20	5	5	-
CO02	Number of enterprises receiving grants	10	3	3	-
CO04	Number of enterprises receiving non-financial support	20	5	5	-
CO24	Number of new researchers in supported entities	514	80.19	86.7[69]	+8%
CO26	Number of enterprises cooperating with research institutions	10	5	5	-
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects	10	5	5	-
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects	5	4	4	-

[68] Discussion with Project Partnership.
[69] As of December 2021.

6.4.5 Key Achievements (to April 2022)

Discussion with the project partners indicates that they consider the following to be amongst the CPM project's key achievements (as of April 2022):

- In terms of the impact on the region, the project partnership outlined that the project has:
  - Contributed towards greater collaboration between academia and clinicians particularly in the NW of the island of Ireland.
  - Developed and strengthened cross-border collaboration allowing for more patients to participate and a greater understanding and insight into different healthcare systems
  - Developed greater collaboration with small and large enterprises in the region increasing the potential for commercialisation of products arising from research
  - South/ North/ Scottish collaborations through the CPM funding permitted capacity building, shared resources, learning and skills development across all partners affiliated with the research cluster.

- The project lead noted that each of CPM's five Research Clusters (RCs) achieved their aims (as outlined in Table 6.1), for example:
  - RC1 improved the human interpretation of the ECG and the machine interpretation of the ECG (or an optimal man-machine model for interpretation).
  - RC2 developed key performance indicators and a comprehensive clinical database with more than 6,000 patients. In addition, the project evaluated the key outcome indicators for Emergency Surgery and created digital templates for machine learning (AI) when there is enough data available to do so.

- The project partnership noted that as of April 2022, there were 2 Invention Disclosures filed and one underway.
- The project lead highlighted that the project joined with the CTRIC TMED annual conference, which occurred in 2017, 2018 and 2019. In addition, the project held a closing event in March 2022. Project partners also attended and presented at 23 conferences.
- The project lead noted that the project partner NUIG was included for their Health Economic and dementia-specific expertise, which resulted in 4 published papers assessing the economic impact of the findings.
- In terms of the progress of the participant PhD students, the project lead indicated the following:
  - 5 are complete and are now in employment;
  - 1 has submitted their PhD, and is in employment; whilst
  - 4 are yet to submit their PhDs, 1 of which is in employment.

An overview of the project's key achievements by research cluster is provided overleaf.

Table 6.6: Key Achievements by Research Cluster	
Research Cluster	**Key Achievements**
RC 1 Primary coronary intervention (PCI) in myocardial infarction (heart disease)	• A Researcher (PhD student) identified a major limitation of the current use of electrocardiograms in diagnosing cardiovascular disease and identified electrode lead misplacement to be responsible. This work was selected to be indexed as an evidence document with the National Institute for Health and Care Excellence (NICE) https://tinyurl.com/j5n2np7u and also showcased in the Cardiology Advisor: https://www.thecardiologyadvisor.com/general-cardiology/machine-learning-to-detect-ecg-electrode-misplacement/ • A Researcher (PhD student) identified through a retrospective clinical review that despite initial contact with the cardiac unit, the vast majority of patients who have a heart attack is not initially identified as such and therefore are not admitted to a cardiology bed. This leads to additional work and delays in definitive treatment due to other teams becoming involved and multiple ward moves. Furthermore, it was identified that there was poor communication between departments. This work directly led to the development of an online triage form (form stream) used by coronary care nurses which allows real-time electronic recording of decision-making and the ability to audit triage decisions. The coronary care nurses triage over 3,000 ECGs every year and this system has greatly improved communication between departments and clarity of triage decisions[70]. • A Researcher (PhD student) developed a digital triage form to assist the nurse activators in the coronary care units. These nurses must decide whether to accept or turn down patients for an emergency procedure called a primary percutaneous intervention. Until now nurses used written notes. Staff are required to simultaneously record details for the patient having a heart attack and make a decision concerning what clinical care pathway should be activated for that patient. Additionally, this new digital form will greatly improve the ease of audit to help identify improvements that could be made in this part of the patient's clinical care pathway. The researcher also performed a study which identified key features in an emergency heart attack patients' care pathway that were imperative to the patient outcomes. These features are being used to develop a clinical decision-making algorithm to improve clinical decision-making for referring patients to the correct department to avoid delays in appropriate treatment. • The RC lead had become a board member of the European Association of Percutaneous Cardiovascular Interventions (EAPCI), this together with the group's invitation to participate in the ESC digital health journal has raised the profile of the RC and highlighted expertise in digital cardiology. Several research grants have been funded to RC members, including most recently RC members were invited to be co-applicants in a Northern Ireland Multimorbidity and Research Discovery project funded by the NIHR.
RC 2 Emergency surgery	• The project has achieved the following milestones under RC2: – Created an agile EGS registry with a defined data dictionary – Provided insight into the pattern of EGS Surgery and its management (over 5000 patients enrolled) – Established and evaluated new key outcome indicators in EGS Surgery – Defined new pathways to manage common conditions – Published innovative research in EGS in the international literature – Created digital templates to facilitate IA and machine learning in the future – Greater involvement of patients and introduction of PROMs into EGS – Formalised interregional links for collaboration across the EU – Start of a new national and international initiative in EGS

[70] 1,000 nurse opinions have been collected on the impact of the digital triage form which showed a positive impact of the form in assisting coronary care nurses during the triaging process of emergency heart attacks.

Table 6.6: Key Achievements by Research Cluster	
Research Cluster	**Key Achievements**
	• The RC developed the first-ever EGS registry (with more than 6,000 patients) leading to the identification of the key outcome measures and the redesign of clinical care pathways. • The interdisciplinary academic and commercial cross-border expertise and collaboration allowed the development of an Emergency Surgery Registry allowing for the world's first Hospital Emergency Surgery Report (EMERGE), a study exploring the costs of diabetes in Irish Public Hospitals (benchmarked to save 60 lives, 9,000 bed days and €5 million per annum) and for the development of algorithms to improve the stages of data pre-processing and analytics for dementia diagnosis, prognosis and treatment and care.
RC 3 Acute Kidney Injury (AKI)	• **Patient-focused** – the main aspect of this project was its patient-focused nature. The team recruited 43 AKI patients, 171 CKD patients and 52 healthy controls and followed up on 10 AKI patients, 3 months following initial recruitment and 19 CKD patients, 1 year following initial recruitment over 19 months. While recruitment was ongoing the research project was widely publicised within the WHSCT and LUH to all patients who were attending the clinic, and all outpatient patients were invited to take part in the project by way of a letter sent before their appointment, therefore informing all patients of the work. In addition, posters and displays were put up in the outpatient clinics to advertise the project and explain it to patients, showing the potential benefits and outcome aims. During the recruitment of each patient, a full description of the research was given and a discussion with the patient about their specific experience with their condition was had, allowing for a very patient-focused experience. • **Cross-border collaborations** – This project spanned the Northwest of Ireland, encompassing Altnagelvin Hospital, in Derry/Londonderry, NI (WHSCT) and Letterkenny University Hospital, in Donegal, Ireland (HSC). This was a major aspect of the project as it allowed for cross-border patient recruitment to be conducted and the collaboration of renal consultants from both sides of the border allowing for insight into both healthcare systems. The project partnership noted that this was exciting as it allowed patients from both sides of the border to participate in the research which then provides a very good overall view of kidney disease in the entire Northwest of Ireland. • **Working with two major stakeholders** – This project worked closely with two major stakeholders, Olink and Randox. These companies were involved in the large-scale biomarker research that was a crucial part of this project allowing for large numbers of biomarkers to be measured. This allowed for the analysis of large-scale proteomic data and potential novel biomarkers for CKD progression to be identified. • In June 2020 the AKI research associate played a key role in helping a UU Professor establish a high throughput Covid-19 testing procedure at Altnagelvin Hospital. This essential work enabled the Cytopathology laboratories to process 300 samples per day and had a significant impact on virus control in the local area. During this time the research associate also began the first phase of the NI seroprevalence study with UU and QUB. The primary objective was to assess random population samples from across NI for Covid-19 antibodies, every 3 months. The results were reported to Public Health England and identified geographical regions of concern, and informed the best vaccination and back-to-work strategies. The research associate was also central to two Ulster University-led research projects: COVRES1 identified genetic changes that could help identify why some patients react severely to Covid-19 and COVRES2 (which was ongoing in April 22) aims to identify immune system biomarkers associated with severity and determine the long-term health impacts in mild and severe patients.
RC 4 Unscheduled Care in Diabetes	• This RC built capacity in the area with: – Postdoctoral experience; – Doctoral students to completion; – Research nurses with expanded roles; and – Management experience.

Table 6.6: Key Achievements by Research Cluster	
Research Cluster	**Key Achievements**
	• This RC improved healthcare outcomes. For example, the RC developed an evidence-based protocol for a 'treat and leave', and the need for ongoing referral for use by the Ambulance service, and the RC identified that 'Freestyle Libre' can be used in acute care. Patient feedback on the FreeStyle Libre was as follows: – "I think if we were able to introduce FreeStyle Libre in the wards it would be a real game changer for a lot of patients…it would be really revolutionary…" – "I found it (Libre) absolutely fantastic. Absolutely. And I really, really appreciated that…. It's the best control I've had in years."
RC 5 Diagnostic Accuracy in Dementia	• Biomarkers for Alzheimer's disease – the RC identified novel endocannabinoid and proteomic biomarkers of mild cognitive impairment and dementia. • To encourage the clinical adoption and further evaluation of the proposed accuracy-vs-time optimisation algorithms (i.e. humans-in-the-loop machine learning), the project implemented a sandbox-like toolbox with a graphical user interface to evaluate user-chosen subsets of assessment items. By optimising diagnostic accuracy, assessment time cost and other costs (e.g. financial cost), the RC redesigned predictive and efficient dementia diagnostic assessments and developed a sandbox interface to facilitate evaluation and testing by clinicians and non-specialists (e.g. policy decision-makers). This will in turn lead to more realistic optimising and redesigning of dementia diagnostic assessments. An intellectual property (IP) right was being prepared to be secured and issued to a collaborative industrial partner(s). • **The added value that the funding contributed to** -The funding has allowed research cluster members to expand networks within Northern Ireland and the Republic of Ireland. For example, the research cluster has established a new collaboration with Queen's University Belfast on applying AI to detect Dementia Lewy Bodies more accurately than clinician diagnosis. In another example, the research cluster has collaborated with a leading MEG-dementia research group in Spain to investigate the use of magnetoencephalography (MEG) to detect mild cognitive impairment and Alzheimer's disease, leading to several published journal papers. • Several research grants (e.g. ARUK, GCRF, HSC R&D PHA and The Atlantic Philanthropies, UU Research Challenge Fund) have been funded to RC members. The most recently awarded/funding came from NIHR (Northern Ireland Multimorbidity and Research Discovery project) and an Invest Northern Ireland-funded Proof of Concept award. • Members of the research cluster are also members of the international Deep Dementia Phenotyping (DEMON) Network, which applied AI and data science to dementia research. The research cluster lead is the co-lead for the DEMON Network for Northern Ireland. A National Strategy white paper on AI and dementia was prepared. • Some members of the research cluster received the 2019 Ulster University Research Excellence Award, Business Category, Business Partnership Category: SME (under 50 employees), based on their collaboration with Nightingale/Healthcare Analytics in dementia data analytics work.

6.4.6 *Progress toward the Project's Stated Objectives*

The CPM Project Partners note the following concerning the progress made towards the project's stated objectives:

Table 6.7: Project-Specific Objectives (at March 2022[71])		
Project Specific Objectives	**Level of Achievement**	**Explanation**
1. To establish a 'Centre for Personalised Medicine; Clinical Decision Making and Patient Safety (CPM)	Fully achieved	The CPM was established, and outputs were reported quarterly to SEUPB. There were no deviations from the original objective. The CPM included a total of 14 partners with 12 partners receiving a budget. These included - 4 research institutions (UU, LYIT, UHI, NUIG), 3 health partners (WHSCT, LUH, NHS-H) and 5 enterprises (Optum, Randox, NICRS, Voscuris (previously Clinishare) and Health Care Analytics (Arc-Net)). The Letter of Offer was signed on 26 June and the partnership agreement was finalised on 20 December 2017.
2. By 1st April 2017, to establish 5 research clusters (RCs)	Fully achieved	All five research clusters were established, and recruitment began when the Letter of Offer was received.
3. By 1st April 2017, to commence work plans with all selected existing staff allocated to the project	Fully achieved	All workplans commenced by 1 April 2017 as preparation was underway before receiving the Letter of Offer. All existing staff worked on the project except for two - which were replaced when required.

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

It was anticipated that the CPM project would:

- Produce 13 peer-reviewed REF[72] standard journal publications in the H&LS 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).

As of April 2022, the project partners had produced 16 peer-reviewed REF-standard journal publications in H&LS journals with cross-border authorship and with the potential to create economic impact, the journal titles are as follows:

1. Wearable technology-based metrics for predicting operator performance during cardiac catheterisation;
2. Data-driven feature selection and machine learning to detect misplaced V1 and V2 chest electrodes when recording the 12-lead electrocardiogram;
3. An exploratory analysis investigating blood protein biomarkers to augment ECG diagnosis of ACS;
4. Intra-operative gallbladder scoring predicts the conversion of laparoscopic to open cholecystectomy: a WSES prospective collaborative study;
5. A practical computerized decision support system for predicting the severity of Alzheimer's disease in an individual;
6. A value proposition for natriuretic peptide measurement in the assessment of patients with suspected acute heart failure

[71] Source: Partner Progress Report 20 – This was the latest collated partner progress report.
[72] Research Excellence Framework. The REF is the system for assessing the quality of research in UK higher education institutions.

7. Machine learning techniques for detecting electrode misplacement and interchanges when recording ECGs: A systematic review and meta-analysis;
8. "Quality Outcomes in Appendicitis Care: Identifying Opportunities to Improve Care"
9. Factors Influencing Hospital Conveyance Following Ambulance Attendance for People with Diabetes: A Retrospective Observational Study;
10. Multi-time-point data preparation robustly reveals MCI and dementia risk factors;
11. (2020) Readmission to Hospital Following Laparoscopic Cholecystectomy-A Meta-analysis.
12. Exploring variation in ambulance calls and conveyance rates for adults with diabetes who contact the ambulance service: a retrospective database analysis;
13. Estimating and Examining the Costs of Inpatient Diabetes Care in an Irish Public Hospital;
14. Comparing Single-Page, Multipage, and Conversational Digital Forms in Health Care: Usability Study;
15. Systematic Review and Meta-Analysis of Wound Bundles in Emergency Midline Laparotomy Identifies That It Is Time for Improvement;
16. Quality Assessment in acute care surgery.

In addition, the project partnership indicated that the project has produced 56 other high-quality peer-reviewed publications (23 conference presentations/papers and 33 abstracts).

6.5 Best Practice and Learning

This section considers whether the Co-Innovate project has resulted in any areas of best practice and learning.

Examples of best practices and learning cited by the project's partners include:

- The delivery of scientific meetings which brought together the academic institutions to facilitate knowledge transfer and good practice; and
- The project was undertaking a retrospective review of patients' records to identify opportunities to improve workflow and the management of patients to increase levels of patient care.

Learnings/Recommendations for SEUPB

The project partnership outlined that the use of EMS for enterprise partners needs to be addressed going forward, as enterprises were not willing to provide the level of information requested to verify claims.

6.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

The CPM project partners suggest that they implemented several activities to enhance the effectiveness of cross-border collaboration concerning 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 was 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 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, and 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 the reliability and accuracy of the study findings. As a result of the CPM project, the clinical partners [WHSCT, LUH, NHSH] were able to undertake bigger studies than would be possible by any one partner working alone. The collaboration, therefore, provided a unique opportunity for high-quality research on five challenging healthcare problems facing the predominantly rural populations of the eligible region. The clinical, academic and enterprise partners jointly recognised the potential of a personalised medicine approach to address these problems.
Joint Implementation	The CPM project was 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 sought to move beyond current 'state of the art' healthcare delivery. • Building upon the research expertise that existed 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 existed 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 existed 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 was contributing to the overall implementation of the project and the governance arrangements, with participation in the project board/steering committee and patient advocacy groups being carried out on a cross-border basis. Each RC contained cross-border partners to ensure the necessary expertise and critical clinical mass for successful completion and shared learning.
Addressing Cross-Border Need	The project partners noted that the eligible region was characterised 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 noted that there were 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 were compounded by difficulties in the recruitment and retention of high-quality clinical staff [manifested by high usage of locum /agency staff]. The project was developed around five disease areas, each selected because of the healthcare challenges they posed in the ER and the opportunity that existed to align clinical, academic and industrial expertise to develop novel approaches to clinical management based upon the disciplines of personalised medicine. The partners suggested 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 were 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 the reliability and accuracy of the study findings. By working together, the clinical partners were able to undertake bigger studies than would have been possible by any one partner working alone. In addition, the involvement of trans-jurisdictional clinical sites gave depth to the projects and allowed the researchers to compare and contrast different but complementary clinical systems.

The project lead noted that the key added value aspects of the project included:

- Building the research capacity especially of the nurses in the ER, as nurses are not typically included in research projects;
- The ability to link health care services on a cross-border basis and look at pathways on a cross-border basis. In addition, LUH had not previously been in a large-scale project, therefore WHSCT shared their knowledge and experience of governance and protocols.
- CPM's management team at Ulster worked closely with the co-located SPIRE 2 and ECME staff across common Doctoral College activities including generic training and development of PhDs and delivering on the Marie Curie principles for research.
- CPM's project partners also noted that they undertook several informal meetings with the other INTERREG VA project managers.

The project lead provided the following examples of new ways of working/partnerships/relationships that have been created as a result of activities carried out within the project:

- The NI Ambulance Service did not have research processes before CPM, and as a result of the project there is now a research process established in NI;
- New partnerships and relationships were developed, particularly for LYIT and the enterprises involved. For example, enterprises gained access to the health service.

6.7 Impact on Business and Industry

This section considers the impact of the CPM project on businesses and industry within the eligible region.

The project engaged with and supported the following five Enterprise Partners (EPs) (three of which also received financial support):

- Voscuris
- NICRS
- Randox
- Optum; and
- Healthcare Analytics.

The project partners worked with the five EPs to translate laboratory and basic science discoveries at levels 3 to 7 on the TRL. The project lead indicated that whilst not all EPs received the same support, the project provided the following to at least one EP:

- Access to clinical cohorts from the Healthcare partners;
- Feedback from clinical or laboratory personnel on the performance of the EP's tests and its impact on workflows;
- Clinical advocacy;
- Training opportunities (e.g. on GDPR and research governance);
- Cost-benefit analysis on assays/equipment/protocols – whilst it was envisaged that Randox would place their equipment into the hospitals, it was agreed that this was not effective or efficient and instead samples were sent to Randox premises.
- Publications and dissemination of advantages of new protocols;
- Opportunity to scale into commodity products, albeit this will be a long process.

For example, for Vosuris the support included:

- Clinical and academic feedback on Voscuris technology and its application within the various research clusters of the CPM.
- Use of case scenarios for development and evaluation, particularly in the areas of digital results presentation and mobile data collection/questionnaires.
- Innovation challenges, including addressing AKI polypharmacy risk factors and the difficulties in maintaining ECG interpretation skills in healthcare staff with low or infrequent task repetition.
- Access to expertise and insight into future research outputs and healthcare challenges.
- Enhanced credibility when seeking investment funding.

Whilst NICRS received training (e.g. PPI, Data Protection (Dublin) and other CPM-related training regarding research governance run through the WHSCT and UU), transfer of Knowledge (scientific knowledge through TMED and non-scientific knowledge through networking for example around health services research processes particularly concerning ethically approval for research and cross-border differences), and was a member of the management team which allowed for the transfer of knowledge across all judications and research areas.

In terms of outcomes, at the time of consultation with the project manager (April 2022) four of the five enterprises had provided information on, and the impact of, their involvement in the CPM project. Examples of the outputs/outcomes reported included:

- Funding applications were made in collaboration with project partners (e.g. WHSCT, CTRIC, and LYIT);

- Knowledge transfer e.g. the Voscuris team were able to use the registry questionnaire as a use case for gaining user feedback and further development of mobile data collection tools, with the potential to replace the RedCap solution if suitable. The insight gained from this collaboration informed the later development of the Voscuris Covid Note app, a tool for enabling patients experiencing post-covid syndrome to record their symptoms.
- The Centre has provided a structure for access to clinical and research expertise and insight into unmet clinical needs across several conditions.
- Creation of new relationships and partnerships.

NICRS stated that *"Participation in the CPM has provided significant benefit to NICRS particularly as an SME. The Centre has provided a structure for access to clinical and research expertise and insight into unmet clinical needs across several conditions. NICRS has also been able to foster relationships with project participants that will be maintained through collaborations beyond the CPM."*

An overview of the enterprises (four of the five) involved in the CPM project is provided in Appendix IX.

6.8 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 Cohesion Policy and EU 2020 objectives;
- The horizontal principles of equality and sustainable development; and
- Other key policies.

6.8.1 EU Cohesion Policy and EU2020 Objectives

The CPM project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and enhancing the competitiveness of SMEs.

The CPM project has helped 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 has also helped to contribute to the Europe 2020 Strategy imperative relating to the levels of GDP (3%) that should be invested in R&D.

6.8.2 The Horizontal Principles

The CPM project partners anticipate that the Programme will serve to contribute (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	The Project Partners considered the environmental impact of the project to be neutral. According to the partners, the project involved no significant travel above what would normally occur. The project team also sought to use digital communications between site teams, where possible. The project partners acknowledged that travel between sites increased the project's carbon footprint but considered that this was more than offset by the efficiencies gained by improved clinical decision-making that ultimately reduced unnecessary travel or inappropriate hospital stays. The project partners considered that social sustainability was addressed in terms of the rural economic development that the project was anticipated to generate. They note that the cross-border region and Northern Ireland had suffered a negative image due to the conflict that had deterred visitors, and inward investors and inhibited local entrepreneurs. The project partners considered that the CPM project developed 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 the Lead Partner, has an Equality Scheme which sets out the University's commitment to and proposals for fulfilling statutory obligations concerning Section 75 and Schedule 9 of the NI Act (1998). The University promoted equality of opportunity, taking account of all Section 75 groups and in addition, promoted good relations between persons of different religious beliefs, political opinions or racial groups. The University had a system in place for accessing compliance with Section 75 duties, had arrangements for screening and carries out Equality Impact Assessments when required. Also, consultation, monitoring, the publication of assessments and monitoring, as well as training formed part of the University's Equality Strategy. An equality scheme action plan accompanied the scheme. These principles were adhered to in the implementation of this project Ulster University, the University partner in Scotland (UHI) and the hospitals in the different jurisdictions were the main employers of the new and existing posts. Each organisation had rigorous policies that applied, including Equal Opportunities monitoring and reporting procedures. All staff in the universities and hospitals had a stated responsibility to comply with the Equal Opportunities Policy. It is understood that UU sought to ensure that this had been enacted by having a representative in attendance at appointment 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 indicated that this was monitored by the CPM Programme Manager.
Equality between men and women	To address the under-representation of women in science, Ulster received a bronze award in the Athena Swan Charter in 2014. This Charter recognises and celebrates good employment practices 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 the lead partner, sought to ensure that all partners working on the project ensured 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 noted that the Research Clusters included 1 female lead and 5 female contributing clinicians and academics, plus female Research Nursing staff.

6.8.3 Contribution to Other Strategies

The Project Partners consider that the CPM project contributed to several 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:	Aligned 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 by the Royal College of Surgeons in Ireland in conjunction with the Acute Hospital division. Their publication was an endorsement of the project and many of the leaders of that project were involved in the DCRA's Emergency Surgery programme. In addition, the project aligned 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 the 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 was 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 the integration of health facilities.
RC4:	Aligned 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	Addressed R&I priorities identified in 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:

- Aligned 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
- Fit 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.
- Aligned with the objectives of the UK Personalised Medicine Catapult Centre and its regional hub in NI.

In summary, the Evaluation Team is of the view that the CPM project has contributed to a range of strategic imperatives that existed across the eligible region.

6.9 Barriers to Cross-Border Co-operation

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

The Project Partners suggest that a key issue encountered was 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 was 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.

6.10 Potential Legacy Impacts

The CPM Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- The newly developed partnerships will continue both nationally and internationally.
- The project has provided a legacy to secure additional funding to advance research. For example, the project has reported early findings of novel prognostic biomarkers for AKI to CKD progression and rapid CKD progression towards ESRD. These findings will lead to future investigative research and may potentially be useful in a clinical setting in the future.
- The data gathered across the project will inform patient practice going forward (e.g. the work that was selected to be indexed as an evidence document with the National Institute for Health and Care Excellence (NICE) and is now adopted by UK NICE).
- The project developed a biobank of biological samples and associated demographic, clinical and social data across a range of disease areas which will be available to support further research.
- The development of the first-ever EGS registry (more than 6,000 patients) is a key legacy as the EGS registry will continue to be used.
- The project expects more publications to be completed after the project's lifetime.

7. RENEWABLE ENGINE

7.1 Introduction

This section of the report considers the Renewable Engine (RE) 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 Rationale for the Project

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

1. The renewable energy (RE) industry was expanding rapidly. New wind, solar and hydropower sources were added at the fastest rate the world had seen in 2015[73];
2. The stock and quality of R&D&I in an economy were 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 for NI from export sales[74].

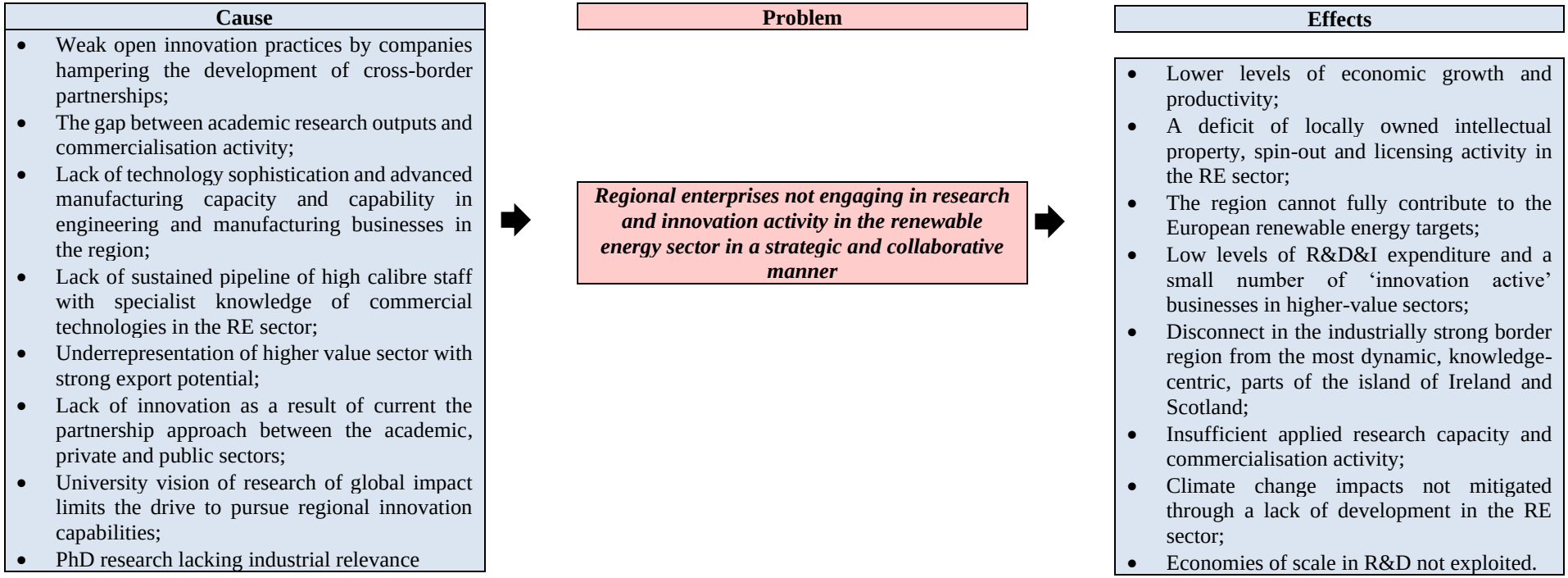
The project partners consider that the rapid growth of the renewable energy industry presented opportunities both locally and internationally, with there suggested to be over 500 companies in the eligible region involved in renewable energy generation, storage and connection. However, the project partners noted that despite a strong policy focus on innovation, expenditure on R&I remained low with Northern Ireland and Scotland having the lowest number of innovation active firms (55%) and patent applications of the 12 UK regions[7576]. R&D expenditure in business and government institutes was well below the UK and international levels. They noted that whilst the Republic of Ireland fared better in the innovation league tables and expenditure was growing, it also remained below EU and OECD average levels.

The project partners' research with businesses in the eligible region indicated that many lacked the awareness, resources and infrastructure to capitalise on the innovation opportunities in the renewable energy (RE) sector. In addition, they noted that PhD level research was lacking industrial relevance on many occasions[77]. The Renewable Engine project was seeking to address this by combining the project partners' industrial linkages, knowledge of the renewable energy sector and academic capabilities.

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

[73] http://www.ren21.net/status-of-renewables/global-status-report/
[74] EAG Competitiveness Report, July 2016
[75] UK Innovation Survey, Department for Business, Innovation and Skills, 2008.
[76] UK intellectual property office, 2010
[77] EAG Competitiveness Summary, July 2016

Figure 7.1: The 'Problem Tree' which the Renewable Engine project sought to address



7.2.2 Project Partners

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

Table 7.1: 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)[78]	UoS	Scotland
5.	Manufacturing NI	MNI	Northern Ireland
6.	Action Renewables	AR	Northern Ireland
7.	Mid Ulster District Council	MUDC	Northern Ireland

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

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

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

7.2.3 Project Overview, Objectives and Activities

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

The Renewable Engine project sought to provide innovation support to businesses that typically lacked physical facilities and equipment to carry out R&I activities to enable them to exploit new technology and sectors. Through this support, the project intended 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 was anticipated that this new collaboration would, for the first time, bring cross-border research centres together across the disciplines of advanced manufacturing **and** renewable energy and this would catalyse the change needed.

[78] 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.

Figure 7.2: The Renewable Engine Research Supercluster

The Renewable Engine project's Letter of Offer identified the project's objectives as being to achieve the following:

- 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.
- 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.
- Develop a novel programme of applied industrial research based on identified needs leading to 57 years of research activity at PhD level or above.
- Coordinate an international board of renewable energy stakeholders to drive innovative forward-looking applied industrial research and initiate policy dialogue.
- Increase the knowledge and awareness within the industry in the cross-border region of R&I infrastructure in the Renewable Energy sector.

R&D activity within RE was delivered through three cross-border research programmes which focussed on three thematic areas:

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

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

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

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.

A series of workshops were delivered by the project partnership to educate manufacturing businesses about 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 on the types of projects that were targeted by the 'Open Call' 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 10 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 must have:

- Demonstrated 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;
- Articulated 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 was 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 was assigned at least 1 PhD student who was working on the project on a full-time basis with full academic support from the project partners. Ten of the PhD researchers were aligned directly to the industry projects plus 50% of each of the Post Doc researchers. The remainder (2 PhD researchers plus 50% Post Doc plus Principal Investigators) were on research projects within the partner institutions. An overview of each PhD project is provided in Appendix XI.

The Project Partners also allocated up to €350,000 to directly support innovation projects through an open call[79]. Successful applicants to the Open Innovation Call could attract funding for their eligible project costs via an additional application round. The percentage of costs that the project partners would pay varied depending on the type of research being carried out and the size and type of organisation involved. The purpose of the grant funding was 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 could 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 have:

- Demonstrated transformational or disruptive, market-led innovation leading to novel, new products, processes or services or bringing about a significant improvement in existing products, processes or services;
- Articulated a clear, anticipated growth and commercialisation impact for the business(es) with considerable, demonstrable potential to lead to a significant return on investment (ROI);
- Demonstrated how the grant funding would be used to support the company's submission under the Renewable Engine Open Call for projects;
- Demonstrated how the grant funding would 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 would be given to proposals that were likely to lead to sustainable gains in productivity and/or access to new overseas markets through export-led business growth.

To deliver the project activities, six work plans were developed with each of the partners responsible for the management of the delivery of a distinct work package, as follows:

Table 7.2: 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 served to ensure that all project objectives were delivered on schedule according to the project work plan, and within approved budgets. Particular attention was paid to financial coordination and the awarding and monitoring of grants and non-financial support to companies as this was likely to have significant state-aid implications. Accordingly, robust project and financial management arrangements were put in place to ensure full EU legislative compliance.

[79] The development grants were awarded in 2 stages, with 5 industry partners (Platinum Tanks, Kingspan, Soltropy, Organic Power and B9 Energy) receiving grant support of €345,786.30,. An overview of the development grants awarded is provided in the Appendix XVI.

Table 7.2: Overview of Renewable Engine Work Plans		
Work Plan	**WP Lead**	**Overview of key activities to be undertaken**
WP 2: Stakeholder Engagement	US	The Project Partners state that their engagement with stakeholders ensured that the needs of industry were correctly addressed and integrated into the programme delivery. They note that their stakeholder engagement activity included 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 implemented 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 was suggested that a key value-added concept underpinning 'Renewable Engine' was 'Open Innovation'. Thus, all 'Renewable Engine' R&I projects were carefully selected through an open and transparent public application process, which only developed projects that could demonstrate the potential for significant strategic impact, met defined commercial return on investment targets and delivered key innovation in the renewable energy sector for local industry partners. The project built 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. This was 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, the establishment of 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 received support, which included the requirements that were necessary to be met concerning State Aid and the financial amount agreed to be contributed by the participating company.
WP 4: Academic Research	QUB	The Project Partners anticipated that 'Renewable Engine' would deliver international excellence in the field of research for advanced manufacturing within the renewable energy sector. The project implemented European best practices for developing effective university-industry partnerships. The principle approach was to provide an accessible R&I infrastructure which targeted collaborative industrial applied research which ascended the TRL ladder and bridged the gap between public and private R&I activity (TRL 2 to 6). It was anticipated that the majority of projects would 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 wished to validate the technology in a relevant environment, were also seen as an integral step

Table 7.2: Overview of Renewable Engine Work Plans		
Work Plan	**WP Lead**	**Overview of key activities to be undertaken**
		towards industrial research. In such cases, it was expected that this would take place at the CREST Centre, Enniskillen where suitable test sites with pre-existing electricity grid capacity were available. State Aid funding rules were applied depending on the category of research being undertaken, the size of the enterprise and the level of collaboration involved. Delivery of the outputs for this work package were 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 was measured through commercial return on investment targets and research target outputs (STs) which included the publication of a minimum of 10 research papers in journals and at conferences recognised within the UK Research Excellence Framework (REF). The focus was on international journals which concentrated on applied industrial research at a high standard of excellence. It was planned that all peer-reviewed journal articles and conference papers would 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 uploaded the final accepted version (post-print) of the article in their institutional research repositories. An "innovation management exploitation plan" was defined to clarify the strategy and actions necessary, and to harmonise the innovation and exploitation activities of the partners. This plan included consideration of technology transfer of project results, IP management stakeholder communication (including policymakers, industry networks and advisors). Delivery of these targets was 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 was implemented to ensure that the objectives, deliverables and academic outputs developed within the Renewable Engine project were widely promoted to local industry, local and regional government, the wider scientific community, and international stakeholders.

7.2.4 Anticipated Outcomes and Results

The Renewable Engine project sought to provide innovation support to businesses that typically lacked physical facilities and equipment to carry out R&I activities to enable them to exploit new technology and sectors.

As noted above, the industrial projects 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.

In addition, it was anticipated that the RE Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 10 peer-reviewed journal articles with cross-border authorship.

7.3 Project Expenditure to July 2022

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 (ERDF plus Government Match Funding) to be expended and claimed by 31st July 2021, towards total anticipated project costs of €6,104,995.

In July 2021, the SEUPB issued a revised LoO (dated 8th July 2021) which approved a project extension, to 31st January 2022, a reallocation of the total grant funding between government match funding and ERDF, and the reallocation of budget between categories, as shown below.

As of July 2022, the project reported total actual expenditure of €5,440,803 equivalent to 89% of the total project budget, however, whilst the project was considered to have been completed at the end of January 2022, this may not reflect the final expenditure position due to the timing of submission and verification of final claims.

Table 7.3: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Total Actual Expenditure[80]	% of the total budget
Staff Costs	1,946,790	1,796,197	92%
Office and Administration Costs	1,074,551	1,000,940	93%
Travel and Accommodation Costs	93,863	87,423	93%
External Expertise and Services	2,451,268	2,029,844	83%
Equipment Costs	538,522	526,398	98%
Total	**6,104,995**	**5,440,803**	**89%**

Discussion with the Renewable Engine project partnership in April/May 2022 indicated that they were behind on the claims process, but were anticipating a slight underspend.

[80] Source: SEUPB's EMS 18th July 2022

7.4 Key Achievements & Contribution to 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.

7.4.1 Key Activities Undertaken (to January 2022)

The Evaluation Team's review of the Renewable Engine project partners' progress reports indicates that key activities undertaken since the second evaluation report (between July 2019 and January 2022) include the following:[81]

Table 7.4: Key Activities

Period	Dates	Key Activities /Points of Note
11	1st July 2019 – 30th September 2019	• South West College (SWC) developed a newsletter that was disseminated, overviewing project activities for the first half of 2019. • A member of staff from SWC involved in this project was named as an author on 2 cross-border research publications in this period. • Researchers across all partners continued to attend conferences and events to disseminate their research outputs.
12	1st October 2019 – 31st December 2019	• All partners participated in the ETP Conference in Scotland. SWC led the Renewable Engine Energy Storage Event at CREST in collaboration with Action Renewables Energy Association. • Across all partners, student progress and attendance at conferences to disseminate findings and publication of journals continued across all the partners.
13	1st January 2020 – 31st March 2020	• SWC represented Renewable Engine at the CASE conference in January and participated in a Renewable Engine future funding workshop with other partners. • QUB was invited to present their findings at a large international conference dealing with rotational moulding (STAR 2020) in Goa, India. They also attended Plastivision 2020 in Mumbai, one of the largest plastics exhibitions in the world. • An Institute of Technology Sligo (IT Sligo) researcher delivered a guest lecture at the 3rd International Conference for photo-conversion chemistry in Korea. The ITS team had 4 research papers/chapters published in this period. • Manufacturing NI delivered a Renewable Engine workshop at the Lough Erne Resort as part of the nationwide "Manufacturing Month"; showcasing the project to attendees from across the manufacturing sector. • Action Renewables delivered a Renewable Engine Energy Storage event to stakeholders within the Action Renewables Energy Association (AREA).
14	1st April 2020 – 30th June 2020	• SWC research continued remotely, enabling them to continue to submit journal articles and complete thesis chapters in this period. • A member of staff completed their Level 7 Certificate in Strategic Management & Leadership.

[81] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time of writing (July 2022). The most recently available collated Project Progress report for the project was for period 19 (July – September 2021), albeit it was in progress and did not detail key achievements. Therefore, key achievements from this period onwards have been taken from partner progress reports.

Table 7.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
		• ITS co-authored and submitted a paper entitled "Covid-19: Rapid prototyping and production of face shields for infection control," to the EUBCE conference. • The University of Strathclyde published an open-access journal article.
15	1st July 2020 – 30th September 2020	• SWC successfully bid for Erasmus+ funding. • Institute of Technology Sligo's PhD student presented a paper at the virtual EUBCE Conference in July.
16	1st October 2020 – 31st December 2020	• SWC attended and contributed to the final research colloquium of the project. SWC engaged with local industry to determine best practices with respect to VR/AR technologies in the manufacturing space. • Furthermore, an SWC researcher undertook training regarding hydrogen safety and supported the Institute of Technology Sligo in the creation of the Sustainability Strategy and Impact Document.
17	1st January 2021 – 31st March 2021	• SWC continued to manage and coordinate various aspects of the project in this period such as coordinating potential consultancy work with Action Renewables. • Furthermore, they made use of new metal printing technologies for team research work and continued work redeveloping the space for this system. • QUB continued with the delivery of new equipment, grant application writing and thesis writing.
18	1st April 2021 – 30th June 2021	• SWC worked with Action Renewables to complete consultancy work focusing on opportunities to recover economically from Covid-19 through sustainable initiatives. • Kingspan and QUB were working on a company project pursuing the development of a hydrogen storage tank with the mould for said tank undergoing manufacture in Belgium in this period. An application for funding to CASE to carry this out was successful. • QUB loaned Platinum Tanks a rotational moulding machine so that joint development projects could be carried out. • QUB also completed the installation of two Fanuc robots. • The University of Strathclyde completed its thesis and published a paper. • The Institute of Technology Sligo presented at ICSSWM and ENVIRON 2021 and submitted a manuscript to the Journal of Physical Chemistry. • SWC and the University of Strathclyde co-organised the "Bridging the gap between Research and Innovation workshop. • A Sustainability Strategy was produced
19	1st July 2021 – 30th September 2021 (From Partner Progress Reports)	• SWC was involved in the setup of, and stakeholder engagement as part of a new cross-border manufacturing cluster (BORMAC) led by IT Sligo which involved disseminating outputs of the Renewable Engine project. • The University of Strathclyde effectively closed out its work with its industry partner Soltropy following the successful conclusion of the company's work. • Furthermore, their PhD student presented a paper at the Global Oceans Conference which was held in September 2021. The paper considered the design of a crane for the transport of heavy components onto offshore wind turbines. • IT Sligo's post-doc researcher completed and submitted a research paper in collaboration with the University of Milano-Bicocca, which was submitted to the Journal of Physical Chemistry C. They also completed a further paper in collaboration with Tyndall National Institute and the University College Cork which was submitted to ACS Applied Nanomaterials Journal.
20	1st October 2021 – 31st December 2021 (From Partner Progress Reports)	• IT Sligo's Research Coordinator was involved in the preparation and submission of a follow-up research proposal to the HEA North-South research grant, to help build on the foundations of the Renewable Engine concept and methodology. • The University of Strathclyde PhD student based at Industrial Systems and Control Ltd was subject to an annual progress evaluation within the University, which they passed without issue. The student at Doosan Babcock was in their writing-up phase and had completed five chapters for their thesis

Table 7.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
		at this point, whilst the student at Booth Welsh successfully submitted their thesis.
21	1st January 2022 – 31st January 2022 (From partner progress reports)	• IT Sligo's PhD students continued to finalise their thesis preparation and carry out validation experiments relevant to their research investigations. Both students also contributed to the video presentations used for the Renewable Engine research Impact Showcase Event, which was held as a hybrid event in Belfast, on the 28th of January 2022. • The Research Coordinator also participated in the meetings to pursue future funding to exploit the Renewable Engine project activities and was involved in the organisation and delivery of the Impact Showcase Event.

7.4.2 External Impact Factors

The Project Partners advise that the project had only encountered minor issues in the delivery of the Renewable Engine project, which did not ultimately have an adverse impact on the overall achievement of the Project's Output and Result indicators and the Priority's Specific Objectives, however, an overview of the issues faced are outlined below.

Impact of the Pandemic

The Evaluation Team's discussions with the Renewable Engine Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Project staff across the project partners and also the project beneficiaries were encouraged to work remotely, whilst others (within the industry partners) were furloughed or made redundant;
- Some PhD experimentation work was postponed, meaning that the data required for PhD projects had not been collected. However, many of the PhD researchers were able to continue writing activities (thesis & journal papers) while working remotely.
- Several of the PhD students became involved in manufacturing PPE;
- The project's ability to hold meetings and conferences was impacted that was anticipated to be used to disseminate information and knowledge transfer activities.
- Expenditure levels slowed due to reduced travel, the postponement of conferences and events and the decision to not proceed with some experimental research work during the lockdown period.

Ultimately, as outlined in Section 7.3, to allow the Renewable Engine project further scope and time to progress its planned activities, the project received a six-month extension to the project to 31st January 2022.

The project partnership outlined (in April/May 2022) that whilst Covid-19 delayed some activities, it did not impact the project as much as expected as the PhDs were nearing the end and were able to easily adjust to online. The main aspect that was affected was the delay in businesses submitting their claims.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit did not have any major or material impact on the project and its ability to achieve its aims and objectives, albeit it was highlighted that there were administrative changes required (e.g. the website address), and there were restrictions on student VISAs, however, this was able to be managed.

Whilst Brexit did not have a substantive impact on the RE project, the partnership noted their concerns that its outworkings had the potential to impact on the likelihood of funding being available for similar cross-border projects in the future.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the RE project included:

- **IP issues impacting the establishment of Collaborative Research Agreements and businesses' recruitment** - The Project's Partners note that there were several protracted discussions with potential industry members concerning background and foreground IP arrangements (being mindful of state aid implications), with the Collaborative Research Agreements[82] taking longer to agree than was originally anticipated. Indeed, as noted, one business that was initially interested in engaging in the project, ultimately decided 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 several 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 salary levels within the private sector and the fact that potential students may be 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 were 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.

7.4.3 Variation to Planned Activities

Discussion with the project partnership indicates that all activities were implemented, albeit there were some adjustments required as a result of Covid-19. For example, the final RE conference had to be held virtually instead of face-to-face.

[82] 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.

7.4.4 *Progress towards the Project's Output Indicators*

As of May 2022, the RE Project Partnership was of the view that it had fully achieved its anticipated (approved) project outputs, with:

- 10 enterprises receiving support (CO01) and non-financial support (CO04), and participating in cross-border, transnational or interregional research projects (CO41) (against the project's original target of 8);
- 8 enterprises cooperating with research institutions (CO26);
- 5 enterprises receiving grants (CO02) (against the project's original target of 4);
- 60.58 research years (against the project's original target of 57.05); and
- 4 research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 7.5: Progress towards the RE Output Targets

Output Code	Description	Programme Output Indicator Target	Renewable Engine Project Target	Progress as of May 2022[83]	Variance against project target
CO01	No. of enterprises receiving support	20	8	10	+25%
CO02	No. of enterprises receiving grants	10	4	5	+25%
CO04	No. of enterprises receiving non-financial support	20	8	10	+25%
CO24	Years of PhD (or above) level research	514	57.05	60.58	+6%
CO26	No. of enterprises cooperating with research institutions	10	8	8	-
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	8	10	+25%
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	4	4	-

[83] Source: Discussion with Project Partnership.

7.4.5 Key Achievements (to May 2022)

Discussion with the project partners indicates that they consider the following to be amongst the Renewable Engine project's key achievements (as of May 2022):

- The Project Partnership were of the view that a very strong partnership had been formed through the project which allowed for successful collaboration. The Project Partnership outlined that as a result of this new relationship the partnership plans to continue working together, and will be applying for further funding (for example Peace Plus).
- SWC's Renewable Engine won the Research with Impact prize at the Green Gown Awards 2021[84]. The College was the only further education college on the island of Ireland to make the shortlist and competed with institutions including Lancaster University, London College of Fashion and the University of Portsmouth for the Research with Impact – Institution prize. The awards' judging panel in their critique described Renewable Engine as *'a really impressive project that is an exemplar for how a college group can work with businesses on sustainability projects that benefit companies, students and society.*'
- The RE project provided PhD students with a more rounded PhD experience which included team-building outdoor pursuit activities (pre-Covid), and working on identified industrial needs gave a 'real world' aspect to the research that provided practical experience and access to expertise and knowledge, which enhances their CV and job opportunity prospects. In addition, through the Renewable Engine project, the PhD students have developed their 'softer' skills such as communication. The project partnership highlighted that a PhD Researcher, working alongside Organic Power Ltd received the Environmental Science Association of Ireland (ESAI) "Postgraduate Researcher of the Year award 2020". The researcher has published six papers in high-impact journals such as Renewable and Sustainable Energy Reviews, etc. His research findings were disseminated at four national and seven international conferences, including the European Biomass Conference and Exhibition (EUBCE) and the Energy Technology Partnership Annual Conference.
- At the time of consultation, all PhD projects were completed (or nearing completion).
- The project held 3 Research Colloquium events as a method of exchanging and disseminating the progress and outcomes of the industrial research projects. In addition, the partnership delivered workshops to researchers and partnered enterprises, utilising expertise from the International Stakeholder Group to provide advice and guidance on matters including Intellectual Property, Finance and commercialising research outputs.
- The project achieved a diverse project team with over 50% of the researchers being female and over 8 different nationalities represented.
- The project achieved outputs/outcomes for the industry partners, as it helped to develop prototypes of new products and/or processes. For example, Platinum Tanks developed a prototype solar panel. Further examples are provided in Section 7.7.
- Members of the Renewable Engine International Stakeholder Group (ISG) formed a partnership to successfully secure an EU-funded Erasmus+ project, HySkills. HySkills aims to develop a modular training course enhanced with a practical training focused on the subject of green hydrogen safety skills. ISG members South West College (the UK – Lead Partner), Dublin City University (Ireland) and the European Institute for Innovation-Technology (Germany), with The University of Tromsø (The Arctic University – Norway) and PROMEA (the Hellenic Society for the Promotion of Research and Development Methodologies – Greece) are involved in the project.
- The project partnership outlined that the work undertaken as part of the RE project has contributed to the economy (and will continue to contribute) as it has moved projects closer to market. For example, Kingspan developed a mould to produce liners for hydrogen storage tanks and is continuing the work with the award of funding from CASE to further develop the work undertaken on the project. The CASE project is a partnership between the Polymer Processing Research Centre (PPRC) at QUB, Kingspan, B9 Energy and CCP Gransden which aims to establish a leading design and manufacturing capability for the production of future type IV hydrogen storage vessels using £225k of CASE funding.

[84] The Green Gown Awards recognise the exceptional sustainability initiatives being undertaken by universities and colleges. (Source: https://www.greengownawards.org/about)

- With a global shortage of personal protective equipment (PPE) to fight against COVID-19, a call for support was put out by Sligo University Hospital and the Health Service Executive Ireland. In response to the request, a team of volunteers at the Institute of Technology Sligo set up a mini production line to manufacture face shields for front-line staff. Using 3D printing technologies, Renewable Engine PhD researchers Snehamol Mathew and Seán O'Connor contributed to the development of 12,000 face shields produced over seven weeks. On assembly, the face shields were distributed to front-line services such as hospitals, nursing homes and Garda Stations.

7.4.6 Progress towards the Project's Stated Objectives

Table 7.6 provides a summary of the progress that has been made by the project against its stated objectives.

Table 7.6: Project Specific Objectives[85]

Project Specific Objectives	Level of Achievement	Explanation
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.	To a large degree	Four research institutes SWC, QUB, IT Sligo and UoS AFRC) developed, agreed, and signed the partnership agreement to collaborate with each other. The project involved the recruitment of industry partners who engaged in collaborative research projects and cooperated with the 4 academic partners (see output indicators CO26 and CO41).
Facilitate direct knowledge transfer, technology development and innovation in 8 companies in the Renewable Energy Sector	To a large degree	The full cohort of industry partners signed agreements to collaborate with research partners (see output indicator CO26).
Develop a novel programme of applied industrial research based on identified need leading to 57 years of research activity at PhD level or above.	To a large degree	60.58 research years completed as of May 2022 (see output indicator CO24).

7.4.7 Progress towards the Project's Result Indicator Targets

Per Table 7.7, it was anticipated that the Renewable Engine Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 10 peer-reviewed journal and conference publications.

Table 7.7: Progress towards the RE Results Indicator

Name of Output	Programme Target (annual)	Renewable Engine Project Target	At May 2022[86]
No. of peer-reviewed journal and conference publications with cross-border authorship	75	Minimum of 10	9

The project partnership outlined that the RE project had almost achieved its target of 10 publications with cross-border authorship. As of May 2022, 9 journals with cross-border authorship had been published and 3 were submitted and under review. In total, 41 research journals have been submitted for publication. A list of those publications with cross-border authorship is provided in Appendix X.

[85] Source: Project Progress Report 18– 'Project Specific Objectives'. This was the most recently available collated project progress report.
[86] Source: Discussion with the Project Partnership.

7.5 Best Practice and Learning

This section considers whether the Renewable Engine project has resulted in any areas of best practice and learning.

Key examples of best practices and learning that have emerged during the 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 delivered a series of activities that 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 participated in a two-day away-day during which they were required to present the progress of their respective research projects and 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 provided an opportunity for research staff to contribute to research projects and papers (which they were not primarily responsible for) from their inception;
  - Delivery of 'Group Therapy' sessions and establishment of social media groups where students were provided with the opportunity to discuss issues that they were encountering on their respective projects to identify potential solutions.

  In addition, the PhD students were supervised on a cross-border basis, whereby each PhD student was allocated a supervisor in another area within the eligible region in addition to the ongoing project support from their academic institution. It is the project partners' view that this aspect of the project supported the cross-pollination of skills and knowledge to both expedite the progress of projects and address project-specific issues that arose, as well as contribute to the wider development of the PhD students.

- **Facilitation of tours** of the Project's Partner's respective institutions (before the onset of Covid-19) to highlight their respective skills and expertise, and encourage wider collaboration and sustainability beyond the Programme period;

- **Rotation of quarterly progress meetings** at each of the Project's Partner's respective institutions (before the onset of Covid-19) 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.

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

7.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

The Renewable Engine project partners suggest that the INTERREG VA Programme had presented an opportunity to create a new cross-border R&I supercluster for renewable energy manufacturing. The intention was 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 toward the development of a more competitive, high-value-added economy. Therefore, according to the project partners, cross-border collaboration was 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' integrated joint development, implementation, governance, staffing and financing, which was 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' served 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.

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:

- The project created a cross-border research cluster, a virtual R&I centre, in Renewable Energy and Advanced Manufacturing technologies involving 4 research institutes (SWC, QUB, IT Sligo and UoS AFRC) to bridge the gap between public and private R&I.
- The project facilitated 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. For example, SWC had no prior engagement with the UoS AFRC Catapult centre.
- Co-operation in complementary activities reduced 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 reduce duplication in R&D infrastructure investments and instead exploited 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 growth opportunities; and improved success rate of new products and services by making the innovation process stronger.
- The project was underpinned by an 'Open Innovation' ethos. The project partners suggest that it is increasingly difficult for the industry to innovate and grow in isolation and enterprises need to engage with different types of partners to acquire ideas and resources from the external environment to stay ahead of the competition;
- The improved access to the UK Catapult Centres (through the University of Strathclyde) for NI and ROI companies resulted 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. Indeed, the partners highlighted that the partners are being recognised as an entity having created a critical mass of expertise.

In terms of new ways of working/partnerships/relationships, the RE project partnership noted the following:

- **New relationships formed** - For the academic institutions, the project enabled new relationships and partnerships to be formed, which will be maintained. The academic institutes are involved in follow on projects (e.g. QUB and Kingspan awarded CASE funding) and have continued collaboration in other projects (e.g. Interreg funded Faster project SWC and UoS).
- **New ways of working** - The project partnership outlined that the Renewable Engine project demonstrated new, or at least uncommon, ways of working in terms of having a regional college as a lead partner, industry-led PhD research, an intended collaborative model of working for the PhD students and the development of academic-industry relationships, especially with SMEs who were less likely to have had contact with university-level academics.
- **Synergies and collaboration with other INTERREG VA projects** – Renewable Engine engaged in the informal 'Project Managers' Group' which facilitated open discussion concerning INTERREG and how to approach particular SEUPB requirements. It is further noted that several PhD students from the Renewable Engine project attended the Bryden Centre Summer School at UHI which served to (inter alia) enhance the levels of industry engagements and provide an overview of the project's research and capabilities.

7.7 Impact on Business and Industry

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

The project partnership outlined that Renewable Engine's key message was about enhancing business' research and innovation capacity, through undertaking R&I led and shaped by industry, focused on TRL 4-7 and utilising academic expertise in a way that could be commercially exploited. Essentially, the project worked with academics to translate PhD work into industry.

Renewable Engine held two open calls and allowed businesses to pitch research proposals in areas that they saw as being relevant. The project received 15 applications across the two calls, with 12 businesses deemed successful and selected to participate, ranging from large multinationals (Kingspan & Doosan Babcock) to 1-person start-ups (Soltropy). However, two businesses dropped off. The following 10 businesses participated:

- Booth Welsh Automation
- B9 Energy Storage Ltd
- Caley Ocean Systems Ltd
- Doosan Babcock
- Kastus Technologies
- Kingspan Water & Energy
- Organic Power Ireland Ltd
- Platinum Tanks
- RotoSim Ltd
- Soltropy Ltd.

The project had 12 PhD students, 10 of which were aligned to company projects whilst 2 undertook research which was directed towards the sectoral research goals of the academic partners within Renewable Energy for Advanced Manufacturing. An overview of each PhD project is provided in Appendix XI. The project's evaluation report[87] outlined that there was agreement from stakeholders that the direction of the project was set by engagement with industry from the outset which helped frame meaningful, needed and varied research, to develop renewable energy usage.

The project partnership outlined that the development grants helped further develop the research possibilities. The development grants were awarded in 2 stages, with 5 industry partners[88] receiving grant support of €345,786.30, towards a total eligible cost of €486,278.20. An overview of the development grants awarded is provided in Appendix XII.

[87] 'Evaluation of the Renewable Engine Project' prepared by RF Associates for SWC, 10 May 2022.
[88] Platinum Tanks, Kingspan, Soltropy, Organic Power and B9 Energy.

The businesses that received a development grant completed a final grant report. In summary, the project partnership outlined that these projects had produced 5 new product prototypes and 2 new processes developed for hydrogen, solar and offshore wind and energy storage sectors, as follows:

- Platinum Tanks - new product prototype for Solar PV;
- Kingspan - new product prototype for hydrogen storage;
- Soltropy - new product prototype and process for solar thermal energy storage;
- Organic Power - new product prototype for small-scale anaerobic digester (SSAD); and
- B9 Energy - new product and process prototype- isothermal compressed air energy storage.

Concerning the support received through the Renewable Engine project, the Managing Director of Platinum Tanks noted the following:

"Platinum Tank's participation in the Renewable Engine Programme has enabled us to use the industry funding to develop and manufacture a prototype solar panel support which will open up new markets for our business in the renewables sector and provide stability for our future growth."

The project partnership provided an overview of the key findings/conclusions from the businesses' end-of-project report which is provided in Appendix XIII.

The project partnership outlined that the 10 businesses also received non-financial support including expert advice, research support and use of equipment which allowed for knowledge transfer between industry and academia.

In addition to 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 a result of their interaction on the project, several Scottish businesses were 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.

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

7.8.1 EU Cohesion Policy and EU2020 Objectives

The Renewable Engine project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation, enhancing the competitiveness of SMEs and supporting the shift towards a low-carbon economy.

Through the potential development of renewable energy technologies emanating from the research, the project has helped to contribute to several 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 also helped to contribute to the target to ensure that 75% of the population aged 20 to 64 should be employed.

7.8.2 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) were overtly focused on developing offshore energy generating technologies and hence contributed to key themes underpinning the Atlantic Strategy including the 'Reducing Europe's Carbon Footprint' theme which advocated that steps should be taken to exploit the Atlantic's powerful waves and strong tides to generate renewable energy.

7.8.3 The Horizontal Principles

The Renewable Engine project partners consider that the project has contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	The project partners suggest that Sustainable Development was core to each organisation and integral to the delivery of their services, and note that the Renewable Engine project had 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 aimed to develop and enhance opportunities for residents of the eligible region and involve communities in the decision-making process. The project aimed 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 saw 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 were 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 underpinned the design and implementation of the Renewable Engine project: Promoting accessibility, valuing cultural diversity, promoting participation, promoting equality of opportunity, promoting inclusive communities and reducing exclusion. SWC as lead partner attended SEUPB's Mainstreaming Equality Training and complied 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 noted that accessibility for persons with disabilities was taken into account when organising venues for training, meetings and events to ensure all had equal opportunity to access and fully participate (ramps, lifts, and toilets). Publicly available documentation including public procurement documents and job descriptions respected the principles of non-discrimination by using language and selection criteria that avoided exclusion of any particular group. Further, to promote a transparent recruitment process all jobs were advertised outside of the partner organisations and a representative interview panel was used for selection. Equality of opportunity was supported through the project's open call process for recruiting industry partners. This process included public advertisement, application and selection based on established criteria to ensure the local industry had equal opportunity to apply. The PMT also used an Equality Monitoring Form to determine if each research project was 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 noted that the integration of gender perspectives was taken into account and promoted throughout the preparation and implementation of the project. Renewable Engine promoted equal opportunity for women and men in the management arrangements of projects, recruiting a gender-balanced Project Board and Project Management Team. To promote gender equality amongst the research personnel, women researchers were recruited. Further, UoS as WP3 lead ensured that both male and female experts in the Renewable Energy and Advanced Manufacturing sectors were represented in the International Stakeholder Group.

7.8.4 Contribution to Other Strategies

The Renewable Engine project partners suggest that by enhancing the R&I capacity of industry and academia, the project supported several 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 were consistent themes throughout the Northern Ireland Innovation Strategy 2014-2025. A key objective of the strategy was to encourage more businesses to innovate by engaging in business to academia and business-to-business collaboration. Renewable Engine increased both forms of collaboration through the provision of PhD research activity to 10 industry partners and further through the development of a unique cross-border 'Research Supercluster' involving high calibre research and industry partners who engaged in open innovation to capitalise on opportunities for innovation. Renewable Engine further complemented the strategy by focusing on resources where there was 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 were considered to be innovation and R&D. It was anticipated that Renewable Engine would 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 had R&D and innovation woven into its strategic objectives. It sought to foster a culture of innovation by supporting high impact world-class research and promoting the development of innovative businesses actively commercialising R&D Renewable Engine sought to improve levels of commercialisation activity for the industry partners in line with the objectives of this strategy, by developing an overarching framework for the 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 was a fundamental component of the Scottish Governments Programme. The strategy emphasised 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 sought to exploit the world-class research, supporting businesses to commercialise their innovation activity through university and business collaboration.
Ireland	• **Innovation 2020 Excellence Talent Impact -** The Irish Innovation Strategy had several 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, enterprises 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 was 'Enterprise Resilience', building supportive systems to pursue new opportunities across a range of sectors. The strategy encouraged enterprises to invest in R&I and to stimulate greater cross-border collaboration between enterprises and Higher Education Institutions (HEIs) with the aim of creating clusters of sustainable competitive advantage in key 'transforming sectors' including green technologies. It was anticipated that Renewable Engine would 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 has contributed towards a range of strategic imperatives that exist across the eligible region.

7.9 Barriers to Cross-Border Co-operation

The Renewable Engine project partners had not identified any barriers to cross-border co-operation that the priority axis was not addressing. However, the project partners highlighted that as the priority axis only includes the border counties of the ROI, there is opportunity for further penetration into the cross-border market.

7.10 Potential Legacy Impacts

The Renewable Engine Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- The project partnership highlighted that there is recognition at a policy level of the need to undertake research for the benefit of the economy, the complication is how to do that. The project partnership is of the view that the RE project is a prime example of how to move research from academia into industry and commercialisation, through collaboration and industry-led research.
- The results and outworkings of the collaboration and work undertaken (including the development grants provided to the industry) will lead to further results beyond the lifetime of the project.
- The project partnership highlighted that the project has contributed to the awareness of, and activity in, the hydrogen market potential in NI. Indeed, there has been and will continue to be growth in the hydrogen market, and the related research undertaken as part of the project will continue to contribute to the development of the hydrogen market and the research will be further progressed beyond the lifetime of the project.
- The partnership has plans to continue working together, and will be applying for further funding (e.g. Peace Plus, Levelling Up Fund etc.).
- An outworking of the project was the development of PhD qualified researchers with skills and knowledge directly applicable to local industry, who will continue to contribute to the economy.
- Members of the Renewable Engine International Stakeholder Group (ISG)[89] have formed a partnership to successfully secure an EU-funded Erasmus+ project, HySkills.

[89] The ISG consisted of international experts from across industry and academia within the Renewable Energy sector that provided top-level strategic direction to the Renewable Engine programme, while also identifying opportunities for exploitation.

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

8.1 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.

8.2 Project Overview

8.2.1 Rationale for the Project

The eligible area was considered to possess some of the best variable renewable energy (wind, wave and tidal) resources in Europe[90]. For example, Scotland possessed 25% of EU offshore wind resources and almost all UK marine energy resources. Northern Ireland and Ireland had some of the best wind resources in Europe[91], and the Marine Institute of Ireland stated that wave energy resources potentially available to Ireland could meet 75% of Ireland's electricity requirement[92].

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 led to wind energy becoming the dominant variable renewable energy (VRE) source in the eligible area. The island of Ireland had 240 Wind Farms and 3083MW installed wind energy capacity[93], equivalent to over a quarter of the all-Ireland electricity supply capacity. Renewables were the single largest contributor to electricity generation in Scotland. In 2014, the largest renewable technology generator was wind with 62%[94].

However, because VRE resources cannot be controlled, integrating them into power systems which had grown around controllable fossil fuel generators required a range of measures to guarantee reliable electricity supply. These measures included 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 had been considerable progress in grid-scale schemes (for example, the underground compressed air storage system examined in the SPIRE 1 Project), there had 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. In such cases, the renewable generators were often simply switched off. Under previous market arrangements, an energy company unable to supply its electricity output to the grid was entitled to 'constraint payments'. However, this subsidy has since been removed for onshore wind[95]. 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 curtailment remained with a significant drop in income for wind farms, meaning energy storage must become an option.

Energy storage provided 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 was higher than baseload provision and renewables supply was at low levels.

[90] UK Renewable Energy Roadmap. July 2011, Department of Energy and Climate Change, URN 11D/698
[91] https://www.economy-ni.gov.uk/articles/wind-map-northern-ireland
[92] http://www.marine.ie/Home/site-area/infrastructure-facilities/ocean-energy/marine-renewable-energy-resource
[93] http://www.iwea.com/windstatistics
[94] http://www.gov.scot/Topics/Business-Industry/Energy/Facts
[95] https://www.gov.uk/government/speeches/statement-on-ending-subsidies-for-onshore-wind

8.2.2 Project Partners

Ulster University and Dundalk Institute of Technology were the partners in the SPIRE 1 project. SPIRE 2 further expanded on this partnership with 2 additional universities as well as 14 additional partners. The project was 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 8.1: 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	UoS	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 was also anticipated to involve several private sector businesses (including two who were formal project partners (Arbarr Electronics Ltd and Sunamp Ltd)). The project partners consider that the benefit of having non-funded partners on the project was that the outputs and impact of the project would 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).

8.2.3 Project Overview, Objectives and Activities

The SPIRE 2 project was a follow-on from the SPIRE 1 project. The SPIRE 1 (Storage Platform for the Integration of Renewable Energy, 2013-2015) project 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 to illustrate the storage technologies best suited to meeting market needs at the small (domestic), medium (distributed) and large (utility) scale.

The project partners acknowledged that while the expansion of centralised, grid-scale storage in the INTERREG region was already underway following the success of the SPIRE 1 project, there had been little progress in the wide-scale deployment of mass-energy storage (MES) which the SPIRE 2 project was based upon.

SPIRE 2, therefore, aimed *"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 sought to consider how the wide-scale deployment of MES could allow very high levels of renewable energy to be integrated into power grids globally. It also assessed how MES could be used to maximise the whole-life performance of VRE systems operating in harsh environments.

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

- 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[96], 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 was to address likely market segment sizes, necessary operational characteristics for optimal market participation and cost/benefit constraints.

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.

SPIRE 2 also aimed 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 was anticipated that the project would boost collaboration between Research Institutes and SMEs and intensify technological innovation and commercialisation in the region.

The project intended 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 were aligned with stakeholder needs.

SPIRE 2's Letter of Offer identified the project's objectives as being to achieve the following:

- 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.

[96] 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.

To deliver the project activities, the SPIRE 2 project partners developed a series of 'SMART Activity Targets' that they anticipated would be achieved through the implementation of 5 technical Work Packages (WPs 2-6). The remaining work packages were WP1 (Project Management) and WP7 (Communications). The key aims of the 5 technical Work Packages (WPs 2-6) are summarised below:

Table 8.2: Key aspects of the 5 technical Work Packages (WPs 2-6)	
WP	**Aim**
WP 2: Market Models	Aimed to 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.
WP3: Technology Development	Aimed to optimise existing distributed energy storage technologies for new electricity markets and develop new technologies to achieve greater market penetration.
WP4: Performance of VRE Sources	Aimed to quantify the decline in the performance of VRE generators in harsh environmental conditions over their full life and develop whole-life energy storage sizing solutions.
WP5: Application and Implementation	Aimed to identify and evaluate a range of approaches to integrate distributed energy storage systems into industry, communities, rural businesses and homes. This was addressed by WP5 which draws on knowledge of WP5 and both acted upon and served WP2 (Market Models) and WP3 (Energy Storage).
WP6: Business Models and Standardisation	Aimed to develop standards for MES/ distributed energy storage and use these to inform policy/strategy for deployment and create education and research pathways to commercialise technologies and generate new businesses. WP6 fed into Sections 10 and 11 to facilitate economic growth through a supply of highly educated developers able to transform research ideas into commercial reality.

8.2.4 Anticipated Outcomes and Results

It was envisaged that the SPIRE 2 would 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 the government's attempts to reach sustainability targets.

In addition, it was anticipated that the SPIRE 2 Project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 78 peer-reviewed journal articles with cross-border authorship.

8.3 Project Expenditure to July 2022

The SPIRE 2 project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €6,462,928 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards the total anticipated project costs of €6,703,246.

In December 2021, the SEUPB issued a revised LoO (dated 14th December 2021) which approved a project extension, to 30th September 2022, and a reallocation of budget between categories, as shown below. The Evaluation Team's review of SEUPB's EMS indicates that as of July 2022, the project had reported total estimated expenditure of €6,016,351 equivalent to 90% of the total project budget.

Table 8.3: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Estimated Expenditure in July 2022[97]			
		Reported to JS by FLC	Pipeline Expenditure (excluding items deemed ineligible by FLC)	Total Estimated Expenditure	% of the total budget
Staff Costs	2,882,648	2,090,906	496,943	2,587,849	90%
Office and Administration Costs	1,328,784	1,002,229	187,941	1,190,170	90%
Travel and Accommodation Costs	102,611	31,593	3,301	34,894	34%
External Expertise and Services	2,003,933	1,723,978	201,955	1,925,933	96%
Equipment Costs	385,269	210,041	67,464	277,505	72%
Total	**6,703,246**	**5,058,747**	**957,604**	**6,016,351**	**90%**

Discussion with the SPIRE 2 project partnership in April/May 2022 indicates that they were anticipating a potential 10% underspend by the anticipated end date. The project partnership highlighted that whilst most partners will spend the majority (if not all) of their budgets, UU will have an underspend due to not being able to recruit a researcher and limited use of the travel budget as a result of Covid-19.

[97] Source: SEUPB's EMS 18th July 2022

8.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the SPIRE 2 project's key achievements 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.

8.4.1 Key Activities Undertaken (to May 2022)

The Evaluation Team's review of the SPIRE 2 project partners' progress reports indicates that key activities undertaken since the second evaluation report (between December 2019 and May 2022[98]) include the following:

Table 8.4: Key Activities

Period	Dates	Key Activities /Points of Note
12	1st December 2019 – 28th February 2020	• QUB participated in the Bryden Centre Conference: 'Engineering the Energy Transition' and published papers in this period. • Strathclyde University was involved in conference preparation. • A BBC Radio Ulster interview was broadcast with a SPIRE 2 academic relating to the project's role in determining future energy systems and Vehicle to Grid (V2G) charging.
13	1st March 2020 – 31st May 2020	• Ulster University had an energy storage PR article published in Energy Storage News. • Sunamp and Climote developed tools and technologies to help support the fight against Covid-19. • Strathclyde University produced several publications on the erosion of wind turbines and these were being reviewed and modelled.
14	1st June 2020 – 31st August 2020	• Ulster University commissioned research into demand side flexibility and smart meters. • The project's Commercialisation Manager attended a University of Cambridge Ignite Summer School on Entrepreneurship. • Barriers and Opportunities for Heat Decarbonisation in Northern Ireland Events and Seminars were held. • Strathclyde University began a new project on environmental effects on wind turbine blades by bird strike with a paper being drafted on this work. • Arbarr commissioned the off-grid system installed in Blackrock Park, Dundalk. • Dundalk Institute of Technology (DkIT) continued energy data collection and analysis at outlying sites as well as the preparation and submission of papers. They were also working with local community groups to further regional energy progress.
15	1st September 2020 – 30th November 2020	• Ulster University engaged in online Commercialisation and Industry Engagement training in collaboration with NWCAM and SkillFluence. In addition, they participated in the HandiHeat Research Analysis and Webinar on 'Energy Options for Rural Dwellers.' • Strathclyde University engaged in further mapping of raindrop erosion on wind turbine blades and assessed the effect of UV light on degradation rate and a large-scale rotating rig for raindrop erosion in addition to furthering mathematical models.

[98] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time of writing. The most recently available collated Project Progress report for the project was for Period 17 (March - May 2021). albeit it was in progress and did not detail key achievements. Therefore, key achievements from this period onwards have been taken from partner progress reports.

Table 8.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
		• DKIT published a paper in collaboration with the University of Perugia, Italy relating to wind turbine ageing. • The SPIRE 2 project carried out a presentation at the Energy Ireland conference with a subsequent article published in the Renewable Energy in Ireland magazine 2020. • DkIT's Community Partner, Dunleer won the Inspiring community award at SEAI national energy awards. Furthermore, a PhD student co-authored a publication with the University of Strathclyde.
16	1st December 2020 – 28th February 2021	• Ulster university updated the website with case study infographics. • Furthermore, one of their researchers developed a NI Energy Flexibility Map tool, whilst one of their PhD students submitted their dissertation and passed their VIVA oral test. • Strathclyde University completed further work on rain erosion mapping and published a paper on this, in addition to publications of work relating to hail erosion modelling and tidal turbine materials. • DKIT had further peer-reviewed publications in association with the University of Perugia in this period.
17	1st March 2021 – 31st May 2021 (From Partner Progress Report)	• The SPIRE 2 and NWCAM projects in association with SKILLFLUENCE delivered CV Coaching sessions for SPIRE 2 PhDs. • 3 Ulster university students submitted their theses. • Strathclyde University students submitted and had several journal papers published in this period. A paper on the erosion of tidal turbines in collaboration with the University of Edinburgh demonstrated a basis for using erosion maps for optimising mechanical properties of the polymer matrix in polymer-based composites. • Furthermore, several conference presentations, keynotes and invited talks were delivered in this period. • A QUB student submitted their thesis and successfully passed their VIVA in this period. Subsequently, they were awarded their PhD subject to minor corrections.
18	1st June 2021 – 31st August 2021 (From Partner Progress Report)	• Strathclyde University began leading the ISO committee concerning generating standards on hail erosion testing of wind turbine blades. • Furthermore, Strathclyde University got the slurry pot erosion rig up and running and was in the process of calibrating it**.** • One of the PhD students graduated from QUB during this period. • Arbarr was working on an Off-Grid system in Ireland and the UK.
19	1st September 2021 – 30th November 2021 (From Partner Progress Report)	• An Ulster University PhD student passed their VIVA in September and secured employment with The Energy Systems Catapult. • The Northern Ireland Housing Executive (NIHE) launched its Reaching Rural Strategy, with SPIRE 2 initiatives: Rural-led Energy Transition (RuLet) and Handiheat both featured as case studies in this strategy document. • The enhancement of laboratory activities and capabilities through SPIRE 2 enabled TRIBOS (Strathclyde University's research group) to increase its engagement and visibility. For example, the TRIBOS group hosted the composites group of the University of Edinburgh and hosted the head of SSE Renewables in this period. • DKIT sent an application in collaboration with Arbarr to the INTERREG VA supported Co-Innovate programme to support the development of a mobile battery product, targeted at the off-grid energy supply industry and remote energy users. • QUB purchased a 100TB Novatech storage server, for PhD students to store/access data provided by SONI/Eirgrid & Kilroot Power station.
20	1st December 2021 – 28th February 2022 (From Partner Progress Report)	• Two Ulster University students passed their VIVAs in this period, with one of the students securing a lecturing position in Jordan. • During this quarter Strathclyde University completed the calibration of the new state-of-the-art rain erosion rig. However, the operation of the rig was

Table 8.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
		temporarily suspended pending certification from a structural engineer after some health and safety concerns. • The Strathclyde University group was also involved in academic engagement with a University of Glasgow lecturer expressing interest in collaborating on abrasion. This was a direct result of the SPIRE 2 investment in the group's laboratory facilities. • DkIT concluded their PhD research studies in this period, with further publication and industry engagement also taking place. • DkIT continued to collaborate with Arbarr Electronics and developed a further Co-Innovate project which commenced in January 2022. The aim of this project was to support a staff member at Arbarr to continue the innovation in a mobile battery solution.
21	1st March 2022 – 31st May 2022 (From Partner Progress Reports)	• Work continued on the RuLet initiative with UU analysing the monitoring data from the trial properties. • Two undergraduate energy and engineering students at UU were awarded scholarships by NIE Networks. • An Ulster University staff member delivered a presentation with the Belfast Health and Social Care Trust on delivering sustainable healthcare estates to IHEEM in Dublin. • The SPIRE 2 Project Management team took part in the SEUPB workshop in March alongside teams from the Bryden Centre and Renewable Engine Projects. • During this period Strathclyde University was attempting to get the safety approval certification for the rain erosion rig, however, their attempts were not fruitful. • Thanks to equipment bought through the SPIRE project, namely the Anton Paar TRB3 tribometer, Strathclyde University managed to establish a short collaborative project, envisaged to last three months with TATA Steel NL.

8.4.2 External Impact Factors

The Project Partners advise that the project has encountered several issues in the delivery of the SPIRE 2 project. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the SPIRE 2 Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, their project partners or direct beneficiaries commenced working remotely or were furloughed;
- The project was unable to access laboratories and there were delays in onsite activities due to lockdown and social distancing measures;
- Whilst some of the work with enterprise partners was able to continue (such as the top-down modelling of SONI and NIEN data that is required along with the wind curtailment data from ESB), the installation of equipment in NIHE houses was considerably delayed. NIHE's priority was to ensure that maintenance works were undertaken safely and per social distancing guidance;
- Expenditure slowed due to the reduction in travel and some equipment not yet being purchased.
- Many of the enterprises involved were focused on survival and the activities in the project were of lesser priority;
- The project partnership had some concern about the impact of the lockdown periods and restrictions on travel on the mental well-being of researchers, particularly concerning students who moved to the UK/Ireland to participate in a SPIRE 2 project and may have felt very isolated with the current situation (lack of friends/family in the country, along with general uncertainty surrounding the

situation/project etc.). Consequently, the partnership endeavoured to increase its contact through remote means with the PhD researchers;
- Additionally, the partnership notes that some of the student experience has not been as rich as it otherwise would have been.
- The curtailment of networking and travel may impact students' and researchers' ability to present their work. The project is working to identify other dissemination opportunities;

Ultimately, as outlined in Section 8.3, to allow the SPIRE 2 project further scope and time to progress its planned activities, the project received a nine-month extension to the project to 30th September 2022.[99]

The project partnership highlighted (in April/May 2022) that whilst factors associated with COVID did not ultimately have an impact on the project implementing the full activity or achieving the aims and objectives, the pandemic resulted in delays to activities and changes to how they were delivered. For example, all training had to move online. The project lead noted however that as the training moved online and there were delays in other research areas, students were able to complete more training than was originally anticipated. The training provided included advanced software training, commercialisation training and entrepreneurship/ career development training (e.g. CV building).

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit had minimal impact on the project, with only some supply chain issues requiring the need to change suppliers. In addition, the project lead noted that as of April 2022 details of the Prosperity Fund had not yet materialised which could impact, more broadly, research projects going forward.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the SPIRE 2 project included:

- **Changes to industrial partners** - The Project Partners note that two industry members 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);

- **Businesses' concerns relating to the loss of background IP** - During consultation, the project partners noted that there were delays at the outset in some 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 indicates that there were delays in the recruitment of PhD students to the project. The Project's Partners suggest that this situation may have arisen since several 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;

[99] To facilitate the completion of the Final Evaluation report within SEUPB's required timeframe, discussions with the project partnership were undertaken during April/May 2022, meaning that the project continued to have circa 4/5 months before it was anticipated to complete.

- **Student mobility issues** – Whilst not deemed to be a significant issue, the Project Partners note that they 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 was hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed to conduct research.

8.4.3 Variation to Planned Activities

Discussion with the project partnership indicates that a small number of activities had to be amended including:

- The companies involved changed, for example, AES was sold;
- Delivery had to move online as a result of Covid-19.

8.4.4 *Progress towards the Project's Output Indicators*

As of April/May 2022, the SPIRE 2 Project Partnership was of the view that it had fully achieved all but one of its anticipated (approved) project outputs, with:

- 16 enterprises receiving support (CO01) and non-financial support (CO04), cooperating with research institutions (CO26) and participating in cross-border, transnational or interregional research projects (CO41);
- 2 enterprises receiving grants (CO02);
- 4 research institutions participating in cross-border, transnational or interregional research projects (CO42).

The project's reporting of 'new researchers in supported entities' (CO24) was behind schedule, with November 2021 being the most recently available number at the time of consultation (April/May 2022), however the project partnership outlined that 86 years' of PhD input was forecast to be achieved by the end of the project.

Table 8.5: Progress towards the Output Targets

Output Code	Description	Programme Target	SPIRE 2 Target	Progress as of April/ May 2022[100]	Variance against project target
CO01	Number of enterprises receiving support	20	12	16	+33%
CO02	Number of enterprises receiving grants	10	2	2	-
CO04	Number of enterprises receiving non-financial support	20	12	16	+33%
CO24	Number of new researchers in supported entities	514	83	81.8[101]	-1%
CO26	Number of enterprises cooperating with research institutions	10	12	16	+33%
CO41	Number of enterprises participating in cross-border, transnational or interregional research projects	10	12	16	+33%
CO42	Number of research institutions participating in cross-border, transnational or interregional research projects	5	4	4	-

[100] Source: Discussion with Project Partnership.
[101] This was the figure at November 21. Consultation with the project partnership outlined that 86 was forecast to the end of the project.

8.4.5 Key Achievements (to May 2022)

Discussion with the project partners indicates that they consider the following to be amongst the SPIRE 2 project's key achievements (as of May 2022):

- The SPIRE 2 project was the enhancement of an existing virtual R&I centre (built on SPIRE 1). Ulster University and Dundalk Institute of Technology were the partners in the SPIRE 1 project, and SPIRE 2 has further expanded on this partnership with 2 additional universities as well as industry partners. The project partnership noted that all research institutions involved have enhanced their R&I activity in the project area as a result of the project.
- A key achievement of the project is the development of 88 peer-reviewed journal articles/conference presentations.
- The project partnership outlined that there were 16 PhD projects, an overview of the project and status of the PhD students is outlined in Appendix XV. In summary, the project partnership outlined the following position of participant PhD students as of June 2022:

  - 10 students had completed their PhDs;
  - 3 students had submitted their thesis; and
  - 3 students were yet to submit their thesis.

  In addition, 10 of the PhD students have already secured employment, 7 in academic-related posts and 3 in industry.

  The project partnership highlighted the positive impact on the PhD students' development having the opportunity to work with enterprises and to work with real live data (e.g. access to NIE data and software).

- SPIRE 2 aimed *"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".* The project partnership outlined that SPIRE 2 has achieved many of these aims and will leave a legacy of research and tools that stakeholders can use to develop business models to deploy distributed energy storage and exploit new market structures as they develop. The project partnership noted that as of May 2022 technology development and economic modelling were continuing.

  The project partnership outlined that examples of the research undertaken in the MES/Distributed energy storage technologies area can be seen in the publications and also the research undertaken by the SPIRE 2 PhD cohort, for example:

  - Research publication - 'Economic Assessment of High Renewable Energy Penetration Scenario in 2030 on the Interconnected Irish Power System'
  - A thesis on how hospital sites could deploy distributed energy storage to both provide the Health Service with more resilient electricity supplies and also allow hospitals to take part in new markets where energy is traded between consumers through aggregators who can use energy storage to meet demand on the current grid.
  - QUB researchers and students have published several papers on deploying energy storage on the current grid and how income can be derived from deploying battery storage. They have also assessed the impact on the electricity supply grid of high penetration of domestic batteries and where this can support the network and mitigate costs of additional demand on the network.

- The project was able to engage with a range of enterprises and organisations including Glen Dimplex Heating and Ventilation, NIE Networks, Ulster Farmers Union, SONI-EirGrid and Belfast Health and Social Care Trust.

- The project partnership outlined the following impacts emanating from the project for the academic institutes:

  - UU's partnerships have built resilience into Energy systems in the Health Sector;
  - A QUB PhD student received 1st Prize for the IEEE Graduate Student Poster, a first for QUB;
  - UU partnership secured new engineering scholarships with NIE Networks;
  - Strathclyde group was invited as academic lead for ISO on hail erosion testing of wind turbine blades.

- As part of the project, QUB built a better working relationship with NIE and was able to access grid data for the first time. This allowed project researchers to undertake network analysis and access to this data will continue beyond the lifetime of the project.
- DkIT worked with SPIRE 2 stakeholder Ulster Farmers' Union to address issues with distributed single wind turbines. Many turbines in the sector have issues with producing too much energy at certain times and therefore dump loads must be used or other amendments to the turbine to avoid exceeding what the turbines can produce. The SPIRE 2 researchers in collaboration with the Ulster Farmers Union were able to identify the solutions which will assist the sector to remain viable and assist in further decarbonising energy in the cross-border territories.
- The project developed a Demand Flexibility map, an interactive tool designed to help develop an effective flexibility strategy and implementation pathway for Northern Ireland[102]. The tool provides a whole energy system model, linking socio-demographic, housing, heating and transport data with known congestion and constraints on the electrical transmission and distribution systems. The tool has been used to:

  - Perform a geospatial assessment of flexibility needs and opportunities at the neighbourhood level;
  - Identify neighbourhoods at risk of being left behind in the energy transition; and
  - Develop a flexible distribution and prioritisation model that gives precedence to vulnerable consumer groups to ensure that there is increased justice in the energy system.

- The SPIRE 2 project expected to generate at least eight intellectual property (IP) disclosures. The project partnership outlined that they sought to capture the benefits and impacts of intellectual property realised as a result of the research undertaken. UU worked with the partners to identify potential IP assets and referred partners to their relevant technology transfer offices for IP evaluation. Whilst no patent applications have come forth (as of May 2022), intellectual assets and know-how have been identified and have created an impact as follows:

  1. SPIRE 2 PhD students and researchers at Strathclyde University developed a Mapping Tool incorporating Met Office Data and Met Éireann data. The tool can be used to forecast turbine blade erosion at various sites. In turn, this information can be used to plan maintenance programmes and also inform future turbine development to support turbine longevity and sustainability.
  2. The SPIRE 2 RuLet initiative has engaged with the Utility Regulator Northern Ireland and Power NI to develop a Flexible Tariff that seeks to optimise the use of curtailed wind energy and support social housing tenants in the transition to electrification of heat.
  3. SPIRE 2 Researchers at UU developed a NI Flexibility Map software platform. The Demand Flexibility map is an interactive tool designed to help develop an effective flexibility strategy and implementation pathway for Northern Ireland. The map is available at https://niflexmap.web.app/
  4. QUB PhD researcher has developed software which identifies generators that produce oscillations and can cause stability/blackout issues. This work has been presented to the Senior Management team at Eirgrid/SONI and the Utility Regulator, which informed their strategy and policy development. SONI and Eirgrid have been trialling the software since November 2020

[102] Available at https://niflexmap.web.app/

and are seeking to develop it further to work in real-time and avoid any instability issues before they occur. The researcher is now employed by Eirgrid to further develop this work.

5. SPIRE 2 QUB Post-doc Researcher has moved into a lead role with a newly formed QUB spin-out company Phasora Ltd. The company aims to build affordable sensors and novel software to aid in the management of increasingly complex electricity distribution networks. Building on knowledge and experience gained through participating in SPIRE2, the Researcher will play a pivotal role in prioritising Phasora's R&D towards applications that are of the highest priority to the industry.
6. DKIT researcher has used know-how gained from his research in SPIRE2 to support the Dunleer community in spinning out a new not-for-profit company called Irish Sustainable Communities Together; this company offers renewable energy solutions to homes, community centres and businesses across the region.

The project partnership outlined that they would continue to work with partners to identify and capture IP assets that can be protected and/or create impact as a result of the project.

8.4.6 Progress towards the Project's Stated Objectives

As reflected in Section 8.2, SPIRE 2's Letter of Offer identified five specific project's objectives. Whilst the SPIRE 2 project's progress reports did not require the project to monitor the extent to which the project was achieving each of the objectives, the Evaluation Team's discussions with the project partnership indicates the following:

Table 8.6: Project's Specific Objectives	
Specific Objective	**Commentary per the Evaluation Team's discussions with the SPIRE 2 project**
1. 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.	The project partnership indicated that there have been several publications in the area of potential new electricity markets which may inform investment decisions, inform system operators and governments on the potential benefits of MES, for example: • 'Economic assessment of auto production, electricity storage and billing adjustments for a fast-moving consumer-goods plant in Ireland'; and • 'Increased Benefit Of ZnBr Flow Battery With 33kWp PV System And Smart Tariff Structure'. In addition, the work of SPIRE 2 has been cited in strategy documents such as the DFE report 'Path to Net Zero' and also the NIE Networks for Net Zero: Delivering a Sustainable Energy System for All.
2. To optimise existing distributed energy storage technologies for new electricity markets and develop new technologies to achieve greater market penetration.	Concerning optimising existing distributed energy storage technologies for new electricity markets and developing new technologies to achieve greater market penetration, SPIRE 2 has worked with its industry partners to both develop their current technologies and also investigate new areas where storage technologies can be deployed, for example: • UU PhD Student research into the improvement of phase change materials which are used in the heat stores of one of the project's partners SUNAMP. • ARBARR have used test equipment purchased in conjunction with SPIRE 2 to test their current batteries in harsh environments with the aim of improving how they perform in hot climates. • SPIRE 2 also engaged with partners to develop control systems with Climote and Sunamp with systems installed in NIHE social housing.
3. 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.	The SPIRE 2 Project Partnership outlined that UoS engaged in extensive research into how wind turbines are affected by erosion in harsh climates. UoS developed a specialist test rig to simulate the effect of rain and hail on different materials. This has led to engagement with both turbine operators and manufacturers. In addition, the project partnership stated that this work will continue beyond the end of the SPIRE 2 project as the test equipment will have a useful life for several years.
4. To identify and evaluate a range of approaches to integrate distributed MES systems into industry, communities, rural businesses and homes.	The SPIRE 2 Project Partnership outlined that SPIRE 2 had identified and evaluated a range of approaches to integrating distributed MES systems into industry, communities, rural businesses and homes. For example, the project participated in a joint research project with NIHE to assess how electrical heating, energy storage and smart control technologies could create new business and ownership models for flexible heat demand in social housing. SPIRE 2 project researchers designed and coordinated a field trial of a range of domestic technologies provided by project partners Climote, Grant Boilers and Sunamp. A sample of 10 HE houses were fitted with standalone or hybrid Air Source Heat Pump heating, along with thermal storage and smart controls. UU is undertaking work with NIE Networks and SONI to model the impacts of extensive uptake of flexible electrical heating systems in NIHE dwellings. If deemed successful, these technologies could be implemented across the NIHE sector. In addition, the project lead highlighted that there are further examples in all the publications and the PhD project.
5. 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.	Concerning developing standards for MES, DKIT has been involved in developing International Standards for Energy Storage and Wind Energy for the International Energy Agency (IEA). DkIT hosted an IEA conference on behalf of SPIRE 2. This work has led to the development of several international standards that will be used globally when deploying renewable energy sources.

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

It was anticipated that the SPIRE 2 project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 78 peer-reviewed journal and conference publications within the Renewable Energy sector with cross-border-authorship and with the potential to create economic impact.

The project partnership indicated that as of March 2022 the project had published 88 peer-reviewed journal articles/conference presentations, however only 39 of which had cross-border authorship. An overview of the publications is provided in Appendix XIV.

Table 8.7: Progress towards Result Indicator Targets[103]

Result Indicator	Programme Target (annual)	Project Target	Actual as at March 2022
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	39[104]

The project partnership noted that there was an inherent issue with the target requiring cross-border authorship, as the SPIRE 2 project 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 a demand on the quality and impact of the research publication as well as critical research protocols. Whilst the project lead highlighted that there were plenty of cross-border workings, it is not reflected in the paper numbers. The project lead indicated that the project is therefore unlikely to achieve the target of 78 publications with cross-border authorship.

The project lead recommended that if there is a requirement for cross-border authorship, there should be a condition at the application stage which encourages a higher number of cross-border partners, perhaps from further afield like Dublin or Galway, as it is essential to have the right partners in place to enable targets to be met.

8.5 Best Practice and Learning

This section considers whether the SPIRE 2 project has resulted in any areas of 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 to overcome barriers to technology deployments;
- SPIRE 2 built 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 utilised 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';
- SPIRE 2 developed a unique Enterprise Engagement process to track collaborative activity which could lead to meaningful collaboration.

[103] Discussion with Project Partnership in April/May 2022.
[104] However, a total of 88 peer-reviewed journal articles/conference presentations had been published.

- There needs to be further work carried out to support gender balance in the sector. Whilst UU and the partners already had schemes in place to promote engineering to female entrants most of the PhD researchers on the SPIRE 2 project were male.
- To maximise impact, there needs to be a closer alignment of PhD projects to industry requirements. From the outset, future programmes should ensure that PhD projects reflect current industry requirements.
- There needs to be flexibility in planning and implementing research areas. As a result of the fast-moving nature of renewables, flexibility in planning and implementing the research is required to ensure the work remains relevant to current needs.
- COVID 19 restrictions limited the opportunities to develop partnerships that could lead to future collaborations. The networking aspect of the PhD and researcher experience is integral to future collaborations.

8.6 Effectiveness of Cross-Border Working 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 concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

The project partners noted that the eligible region features two energy markets, three jurisdictions, different devolved government approaches and policy differences at the national level. Therefore, they suggested 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 required cross-border co-operation to overcome local techno-economic barriers.

The project partners noted that whilst the eligible area as a whole had sufficient research and innovation capacity to create a technology hub with the capability of conducting and commercialising MES research on the scale proposed, it was geographically dispersed over a wide area and spread between three jurisdictions. They considered that no single region within the eligible area could generate enough critical mass on its own to create the virtual R&I centre that had been developed through the SPIRE 2 project. They note that it 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.

According to the SPIRE 2 project partners, there have been considerable benefits to developing and delivering the Project on a cross-border basis, with key highlights identified as including:

- The development of the virtual centre on a cross-border basis has been the key added value, as it has supported the creation and development of new and existing relationships between institutions and enterprises on a cross-border (and inter-regional) basis. The project lead highlighted that the development of networks is essential to further develop the sector as it leads to follow-on projects.
- 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 project lead indicated that the project managers on the CPM, ECME and SPIRE 2 projects met quarterly to share information and knowledge, and were invited to one another's events. SPIRE 2 management team at Ulster also worked 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. It was also suggested that there was some project level interaction between the academics involved in the Interreg VA projects, however, these were not formally recorded or reported.

- In addition, the SPIRE 2 project offered training to the PhD students in conjunction with the NWCAM project, such as commercialisation and entrepreneurship/career development training. It was highlighted as the training brought two different sectors (HLS and Renewable Energy) together this enhanced the PhDs' learning and communication skills, as it required them to consider how to disseminate information to individuals with no existing knowledge of their sector.
- The project partnership outlined that the project did not interact to any great extent with the other Renewable Energy projects funded under the INTERREG Research and Innovation Measure, however the project partners did attend conferences/workshops that these projects also would have attended, for example, the Bryden Centre, Renewable Engine and Spire 2 were showcased during the Engineering the Energy Transition conference, held in February 2020.

8.7 Impact on Business and Industry

This section considers the impact of the SPIRE2 project on business and industry within the eligible region.

The project partnership outlined that the project has supported industry partners to enhance their research and innovation capacity, as the project brought enterprises together with academia to develop and test novel equipment. For example, as part of the NI Housing Executive project (which was still ongoing as of April 2022), the project brought together enterprise partners to test a range of industry technologies (electrical heating, energy storage and smart control technologies) in domestic properties which the project lead highlighted would not have been possible without SPIRE 2. Furthermore, one of the funded partners, Arbarr, in conjunction with DkIT, developed new products concerning providing battery and heat storage to an off-grid island.

In addition, this project created and developed new partnerships between partners in different jurisdictions. Further 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;
- 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.

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

8.8.1 EU Cohesion Policy and EU2020 Objectives

The SPIRE 2 project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation, enhancing the competitiveness of SMEs and supporting the shift towards a low-carbon economy.

Furthermore, the SPIRE 2 project has helped to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth.

8.8.2 The Atlantic Strategy

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

8.8.3 The Horizontal Principles

The SPIRE 2 project partners consider that the project has contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	The project partners noted that the SPIRE 2 project had sustainability at its core, as its central aim was to use mass energy storage (MES) to accelerate the transition to sustainable, clean energy. They suggest that effective electrical and heat energy storage play a critical role in moving to a world powered by a low-carbon sustainable energy system, with the SPIRE 2 aiming to prove that it was 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 impact of SPIRE 2:

Economic Development	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.
Education and Information	Post-Graduate Masters degree level modules were being used for Continuing Professional Development. The Masters in Energy Storage promoted the sustainability aspects of storage. This course was 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. Open workshops disseminated and informed stakeholders. Courses and supporting materials were provided to schools.
Innovation and Job Creation	UK energy storage businesses will contribute £6bn to £34bn to GDP by 2050. Local employment is emerging e.g. Gaelectric was receiving €14 million in funding from the EU to develop an energy storage project in NI. Innovation was 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 businesses e.g. Ulster Farmers Union were anticipated to benefit from the deployment of energy storage as subsidies for onshore wind power curtailment were removed. Value for money was assured through the project's 10 technology disclosures.
Economic Benefits	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 areas of poor air quality. There was a need to develop social intelligence on how the public encounter energy storage at different scales and locations.
Investment for Sustainability	SPIRE 2 communicated with relevant government departments to address match funding. SPIRE 2 employed a dedicated technology translator to engage with future funding opportunities.
Sustainable Communities	The inclusion of two community demonstrators provided guidelines for future deployment.

	Energy and Climate Change	SPIRE 2 promoted renewable energy, energy efficiency, cut energy consumption, reduce the use of fossil fuels and reduce CO2 emissions through the use of energy storage.
	Natural Resources	Targets to use less oil and gas, reduce CO2 emissions and reduce dependence on imports of fossil fuels require renewable energy which requires the use of energy storage to manage variability.
Equal opportunities and non-discrimination	The project partners noted that equal opportunities are embedded within each partner and were applied to each of the organisations that recruited new staff through the project i.e. Ulster, QUB (both NI), Strathclyde (Scotland) and DkIT (Ireland). For example, Ulster University has an Equality Diversity and Inclusion Strategy 2019-2022 which sets out the University's commitment to and proposals for fulfilling statutory obligations concerning Section 75 and Schedule 9 of the NI Act (1998). The University promoted equality of opportunity, taking account of all Section 75 groups and in addition, promoted 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 accompanied the scheme. The application of appropriate equal opportunities policies across the project partners was monitored by the Programme Manager.	
Equality between men and women	The project partners stated that gender equality issues were not treated any differently from any other aspect of equality of opportunity and gender equality policies, implementation and monitoring are addressed as described above for all other equality issues. At the outset of the project, each of the partners were informed of their requirement to adhere to statutory Equal Opportunities Policies including those that relate to gender equality. It is further noted that to address the underrepresentation of women in science, Ulster received a bronze award in the Athena Swan Charter in 2014. This Charter recognises and celebrates good employment practices 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 sought to ensure that the principles of the Athena Swan Charter were 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.	

8.8.4 Contribution to Other Strategies

The SPIRE 2 project partners suggest that the project has supported several 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 aligned 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 focused on delivering cross-cutting activities that integrate policies, market structures and technologies. Furthermore, SPIRE 2 through its energy supply chain structure actively pursued 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 acknowledged 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 draft Northern Ireland Programme (2016-2020) for the Government emphasised a secure energy supply. The project partners note that the draft Programme for Government stated that energy-related CO2 emissions must be cut in keeping with UK targets. SPIRE 2 promoted the integration of clean yet variable renewable energy through the use of energy storage. The PfG recognised that businesses and the workforce remain the key drivers of economic growth and a key outcome was 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 included 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 could progress up the skills ladder, supporting higher levels of productivity. The project partners considered that SPIRE 2 contributed to this agenda with its business-focused research, innovation in novel technology development and skills training through its education programmes.
Ireland	Ireland had legally binding targets for renewable energy to be met by 2020. Ireland's target for energy from renewable sources in gross final energy consumption was 16% by 2020. The National Renewable Energy Action Plan (NREAP) set out the 40% 2020 interim targets for renewable electricity to be achieved by Ireland to meet its obligations under the Renewable Energy Directive. Innovation 2020 was Ireland's five-year strategy for research and development, science and technology. Innovation 2020 set 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 was formed along six broad enterprise themes (ICT, Health and Medical, Food, Energy, Manufacturing and Materials, and Services and Business Processes). According to the Project Partners, SPIRE 2 addressed the energy theme through the development and deployment of energy storage. It also addressed 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 sought to enhance the "Testbed Ireland" concept in that it demonstrated 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 demonstrated 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 suggested that SPIRE 2 concentrated and opened access to quality

	Research Infrastructure and through co-operation enhances Research Excellence (measured by the UK Research Excellence Framework for example).
Scotland	The Scotland Plan for Government stated that manufacturing accounted for over half of Scotland's international exports. The project partners consider that SPIRE 2 addressed 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 stated that it would continue to support the world-class research that existed in our universities and boost collaboration between academia and business, thereby maximising benefits for society and the economy. The project partners suggested that SPIRE 2 contributed to this with the participation of a leading Scottish University and Business. In addition, the partners noted that Scotland's Economic Strategy 2015 stated that Scotland had strengths in a diverse range of sectors including Food and Drink, Financial and Business Services, Life Sciences, Energy, Tourism and Creative Industries and it would continue its focus on these key sectors. SPIRE 2 focuses on energy. Scotland also had an energy policy ("Gone Green") of achieving 100% renewable electricity by 2020 (mostly from Wind). SPIRE 2 was aiming to develop energy storage technologies through appropriate variable renewable energy integration.

In summary, the Evaluation Team is of the view that the SPIRE 2 project has contributed to a range of strategic imperatives that existed across the eligible region.

8.9 Barriers to Cross-Border Co-operation

According to the SPIRE 2 project partners, they have encountered no barriers to cross-border co-operation that the priority axis is not addressing.

8.10 Potential Legacy Impacts

The SPIRE 2 Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project, including:

- The project lead indicated that whilst the project has not yet influenced market activity or structures, the work that has been undertaken inevitability will influence market activity/structure, but more likely post-project. The project lead highlighted that there is ongoing research in collaboration with the Northern Ireland Electricity Networks and the Housing Executive around developing new tariffs for social housing where storage technologies and heat pumps have been installed. This work will assist in the development of new tariffs that will allow and encourage the widespread deployment of energy storage and other low-carbon technologies.
- A thesis focussed on the economic effect of an electricity interconnector between France and Ireland. In the future, this work could inform the economic case for increased market penetration of renewable energy sources.
- The University of Strathclyde completed research into erosion studies using meteorological data to estimate the weathering effects of climate variables, including raindrop and hail impact intensity. PhD student mapped out the rain erosion potential of the UK and Ireland using data from the UK MET office and Met Éireann, as well as data from laboratory studies. The project developed equipment to test materials erosion, and the test equipment will have a useful life for several years.
- The development of the PhD students and researchers will continue beyond the lifetime of the project, as they continue their academic work or move into working in industry.
- The project has influenced policy, for example, it has been cited in or contributed to DfE Pathway to Zero Strategy and NIHE Energy strategy. QUB PhD student's work has been included in the NIE's strategy report 'Networks for Net Zero' as a case study. In addition, DKIT collaborations are informing retrofit legislation in the Republic of Ireland.

- The Department for the Economy had begun the process of developing a new energy strategy to decarbonise the Northern Ireland energy sector by 2050 at the least cost to the consumer. SPIRE 2 researcher and UU academic have published a report which contributes to the Department for the Economy evidence base about the requirement of intelligent metering to gather and communicate real-time usage data as a key building block of a smart decentralised energy system.
- Going forward, the project lead indicated that partners would continue to look for further funding to continue research in the area.

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

9.1 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.

9.2 Project Overview

9.2.1 Rationale for the Project

The Bryden Centre for Advanced Marine and Bio-Energy Research (Bryden) project partners considered that the eligible region had many geographic, economic and demographic characteristics that when combined represented a unique opportunity for the development of renewable technologies and should provide a distinct competitive advantage in a global marketplace. These included 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 had truly world-leading research taking place within its research institutions.

However, several challenges had prevented the regional industry from fully capitalising on this opportunity. Foremost among these was the profile of the regional industry, with companies typically being small- or micro-sized enterprises. As was true for all industries, small enterprises in the renewables sector struggled to dedicate the resource needed to innovate. This was 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 was 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 was a lack of critical mass of highly qualified scientists and engineers capable of translating research into commercial success within these companies. The Bryden project sought to address these challenges.

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

Table 9.1: 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

9.2.2 Project Partners

The Bryden project had 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[105]. Before the introduction of the project, the project partners had been working together for 4-5 years on an innovation centre concept that aimed to address market failures in the eligible region. The project partners suggested that their partnership had been helped by an alignment of cultures and competencies and a desire to build on the expertise amongst the project partners to create a lasting legacy for the renewables sector, and cross-border academic/industry collaborations.

9.2.3 Project Overview, Objectives and Activities

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

1. Marine renewable energy; and
2. Bioenergy.

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

Using a Doctoral Training Centre model, it was anticipated that the Bryden project would recruit 34 PhD students and 5 PDRAs; each of whom would work with industry to produce industrially relevant research with the potential for commercial exploitation and resulting economic growth within the region. Each PhD student was also to be co-supervised on a cross-border basis.

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

Bryden's Vision was 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 doctoral-level scientists and engineers to enable sustained growth for years to come".*

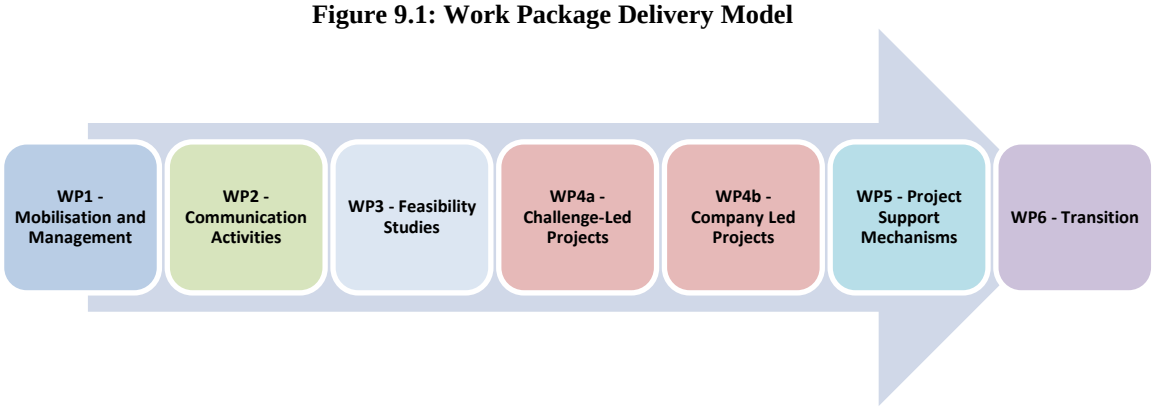
[105] It was anticipated that Dumfries and Galloway County Council and Donegal County Council would provide a conduit to connect Bryden to business enterprises and support networking and dissemination of the project within their regions. This support was to be provided as part of each County Council's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

The Bryden project's Letter of Offer identified 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 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 competencies in the deployment and development of renewable energy technologies.

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

Figure 9.1: Work Package Delivery Model



To deliver the project activities, six work plans were developed, as follows:

Table 9.2: 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

9.2.4 Anticipated Outcomes and Results

Using a Doctoral Training Centre model (as recognised as best practice by RCUK and Horizon 2020), the Bryden project was 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 was also envisaged that businesses would 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 would also occur as all 34 PhD students were anticipated to work closely with industry.

9.3 Project Expenditure to July 2022

The Bryden project received a Letter of Offer (dated 17th July 2017) offering a grant of up to a maximum of €9,367,401 (ERDF + Government Match Funding) to be expended and claimed by 31st December 2021, towards total anticipated project costs of €9,752,680.

In September 2021, the SEUPB issued a revised LoO (dated 30th September 2021) which approved a project extension, to 30th June 2022 and the reallocation of budget between categories.

Furthermore, in March 2022, the SEUPB issued a further revised LoO (dated 22nd March 2022) offering a grant of up to a maximum of €9,365,483 (ERDF + Government Match Funding) to be expended and claimed by 30th June 2022, towards total anticipated project costs of €9,752,680, which in addition to lowering the overall maximum grant offering also approved a reallocation of budget between categories as shown below.

As of July 2022, the project reported total actual expenditure of €8,791,852 equivalent to 90% of the total project budget, whilst the project was considered to have been completed at the end of June 2022, this may not reflect the final expenditure position due to the timing of submission and verification of final claims.

Table 9.3: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Total Actual Expenditure[106]	% of the total budget
Staff Costs	3,103,399	2,687,070	87%
Office and Administration Costs	1,886,117	1,742,477	92%
Travel and Accommodation Costs	114,452	52,809	46%
External Expertise and Services	4,353,001	4,016,264	92%
Equipment Costs	295,711	293,232	99%
Total	**9,752,680**	**8,791,852**	**90%**

Discussion with the Bryden Centre project partnership in April/May 2022 indicated that they were anticipating a potential underspend of c.£400k mainly as a result of the difficulties experienced recruiting and retaining staff.

[106] Source: SEUPB's EMS 18th July 2022

9.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the Bryden Centre's key achievements 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.

9.4.1 Key Activities Undertaken (to June 2022)

The Evaluation Team's review of the Bryden Centre project partners' progress reports indicates that key activities undertaken since the second evaluation report (between December 2019 and June 2022[107]) include the following:

Table 9.4: Key Activities

Period	Dates	Key Activities /Points of Note
11	1st December 2019 – 28th February 2020	• PhD Projects were continuing as planned, with one new student starting at LYIT and one at QUB. • The first Bryden Centre Engineering the Energy Transitions Conference took place in Belfast in February.
12	1st March 2020 – 30th May 2020	• Students and PDRAs participated in several online and virtual conferences during this period including the Environmental Interactions of Marine Renewables conference (EIMR) 2020. • The 2020 Summer School was cancelled in its intended format of a physical week of activity in Letterkenny. However, staff at LYIT worked to present the summer school virtually through a series of talks and training opportunities to students via MS Teams.
13	1st June 2020 – 31st August 2020	• Covid-19 and associated restrictions in this period provided an opportunity for students to work on writing up papers whilst their access to laboratories and fieldwork was hampered. • The University of Highlands and Islands had a paper published in this quarter.
14	1st September 2020 – 30th November 2020	• The Bryden Strategy paper: 'Clean Energy - A positive Future for Northern Ireland Building on our Strengths' was published. • A new promotional video for the Bryden Centre was created for a QUB event entitled 'Chemistry at Work 2020.' • The University of Highland and Islands collaborated with industry and received sign-off from Marine Scotland on a feasibility study.
15	1st December 2020 – 28th February 2021	• Extensions were granted to students, removing many of the concerns over sufficient research results for the completion of their PhD projects. The lockdown in this period due to Covid-19 saw a substantial uplift in the number of papers published.
16	1st March 2021 – 31st May 2021	• A report was delivered to DfE on the potential for Carbon Capture, Utilisation and Storage in Northern Ireland, as part of their development of an energy strategy for NI, with a launch event for the public release version planned for early June.

[107] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time of writing (July 2022). The most recently available collated Project Progress report for the project was for period 19 (December 2021 – February 2022), albeit it was in progress and did not detail key achievements. Therefore, key achievements from this period onwards have been taken from partner progress reports.

Table 9.4: Key Activities		
Period	**Dates**	**Key Activities /Points of Note**
17	1st June 2021 – 31st August 2021	• The aforementioned Carbon Capture Utilisation and Storage for NI Report was formally launched with 56 attendees at the seminar on the topic. • QUB saw a significant increase in interest in the work of the Bryden Centre by industry in this period, particularly in areas which are facing increasing pressure to decarbonise and/or are facing rapid increases in energy costs. • Ulster University hosted the Bryden Summer School.
18	1st September 2021 – 30th November 2021	• Two further QUB students finished their PhD projects and were close to submitting their theses. • Week-long biomass and proposal writing summer school hosted by Ulster University and AFBI was held in September for all of the involved students. The Bryden Centre won £620k from the UK's community renewal fund to support the establishment of zero carbon communities - a concept developed in the Bryden Centre at Queen's to link agriculture and industry to decarbonise communities while transitioning from fossil fuel use. • The project also supported several industry consortia in Northern Ireland in applications to replace red diesel with low-carbon e-fuels.
19	1st December 2021 – 28th February 2022 (From Partner Progress Reports)	• As student projects were ending in this period there was an upsurge in papers being produced by QUB students, with 25 submitted in addition to a further 9 being accepted for publication and a total of 23 published in the period. • During the period letters of the offer were received for two red diesel replacement projects from BEIS and for the Zero Carbon Cooperative project from the community renewal fund. • The University of Highlands and Islands (UHI) had one conference paper published in the journal Energy Research and Social Science Conference. • A further paper was accepted into the Frontiers in Marine Science Journal as part of their Novel Technologies for Assessing the Environmental and Ecological Impacts of Marine Renewable Energy Systems special edition. • Furthermore, a PDRA presentation on knowledge and research into the environmental impact of marine renewable energy devices was included in the "Join the POD" webinar series at Galway Institute of Technology. • An Ulster University student completed and submitted their thesis. • AFBI students had two further research papers published.
20	1st March 2022 – 31st May 2022 (From Partner Progress Reports)	• A total of 4 placements for QUB students began in April and were anticipated to run until the end of June. • There was another upsurge in terms of papers in this period from QUB, with an additional 21 submitted, in addition to a further 9 being accepted for publication and an additional 18 published taking the overall total to 108 papers published throughout the duration of the project to this point. • Two University of Highlands and Islands (UHI) students submitted these. • UHI staff attended a dissemination event titled "Rising Tides: Globally significant energy research in the Highlands and Islands," at the Scottish Parliament. Furthermore, staff and students attended the AllEnergy event in May, showcasing The Bryden Centre as part of the Research and Innovation Zone, whilst students also attended and presented at the World Seabird Twitter Conference in May. • Two AFBI PhD had two further research papers published, in addition to a further paper accepted for publication. In addition, one of the students completed and submitted their thesis.
21	1st June 2022 – 30th June 2022 (From Partner Progress Reports)	• Board members, members of the Steering Committee as well as some students attended the end-of-project showcase at QUB. • A UHI member of the project contributed a presentation on shared seas at the showcase. • One UHI student successfully defended their PhD thesis.

9.4.2 External Impact Factors

Discussion with the Bryden Project Partners indicates that the project encountered several issues during its delivery, that in combination served to slow progress towards the achievement of its output indicator targets (e.g. the number of PhD years). However, encouragingly, none of the issues encountered ultimately had any substantive adverse impact on their overall achievement. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the Bryden Centre Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, project partners or direct beneficiaries started working remotely, whilst some of the industry partners' staff were furloughed or made redundant.
- However, the project considered it fortunate that much of the project could be delivered while not in the workplace. All of the studentships were continuing, those that were modelling-based were unaffected by the lockdown but practical work in labs or the field was not able to be carried out during the period of lockdown. Nonetheless, all of the affected students had results to analyse, papers and theses to write, training, writing software, experimental design etc. A similar situation existed for the PDRAs. In summary, desk-based work was brought forward to replace lab/field/conference activity. According to the project partnership, all the desk-based work was on the schedule but would have been delivered over a longer period.
- Most outreach activities including conferences and student secondments were postponed. However, the second planned 2020 Bryden conference (Environmental Impact of Marine Renewables) was held virtually rather than in a physical meeting. Other outreach such as social media articles did however continue.
- The partnership suggests that the only non-planned activity is the extra management involved in overseeing students and mitigating the impact of the lockdown.
- Expenditure has been lower than anticipated, largely due to reductions in travel and consumables.

Ultimately, as outlined in Section 9.3, to allow the Bryden Centre project further scope and time to progress its planned activities, the project received a six-month extension to the project to 30th June 2022.

The project partnership outlined (in April/May 2022) that Covid-19 had a significant impact on the PhD students with many requiring 3-6 month extensions, and the ability to complete Knowledge Exchange (KE) placements/secondments due to delays and limited enthusiasm from industry to participate resulting in only four KE placements being undertaken. Furthermore, the project partnership outlined that conferences and outreach/networking opportunities were significantly impacted by Covid-19.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit had a limited impact on the project and its ability to achieve its aims and objectives, with foreign students having some difficulty obtaining visas; however, this was able to be managed.

Other Factors

Other specific issues identified by the Project Partners that they suggest impacted the rollout of the Bryden Centre project included:

- **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 was 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 were several changes to aspects of the project's core administrative staff. For example, the finance and administrative assistant role had to be refilled on multiple occasions. Furthermore, Letterkenny Institute of Technology experienced high staff turnover.

- **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 project. The Project's Partners are of the view that this situation may have arisen since several 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. As of April 2022, the project had recruited 36 PhD students and 13 PDRAs, however, 5 PhD students and 2 PDRAs resigned/finished early due to health, financial or other personal reasons.

- **Student mobility issues** – Whilst not deemed to be a significant issue, the Project Partners note that they 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 was hindered due to specific checks and processes required to obtain necessary approval for purchasing equipment and materials needed 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 inadvertently created logistical difficulties in terms of bringing research staff together and promoting a wider 'Centre' ethos.

9.4.3 Variation to Planned Activities

The project partnership outlined the following specific activities that were originally proposed not implemented, or not implemented in the way or extent that was originally proposed:

- The Knowledge Exchange (KE) placements/secondments were not able to take place as expected, with only four students able to participate.
- The student dropout rate was higher than expected, due to various reasons including mental health and Covid-19.

9.4.4 *Progress towards the Project's Output Indicators*

As of April 2022, the Bryden Centre Project Partnership was of the view that it had fully achieved all but two of its anticipated (approved) project outputs, with:

- 127 enterprises receiving support (CO01) and non-financial support (CO04), cooperating with research institutions (CO26) and participating in cross-border, transnational or interregional research projects (CO41); and
- 5 research institutions participating in cross-border, transnational or interregional research projects (CO42).

Table 9.5: Progress towards the Output Targets

Output Code	Description	Programme Target	Bryden Centre Target	Progress as of April 2022[108]	Variance against target
CO01	No. of enterprises receiving support	20	30	127	+323%
CO02	No. of enterprises receiving grants	10	8	4	-50%
CO04	No. of enterprises receiving non-financial support	20	30	127	+323%
CO24	No. of new researchers in supported entities	514	132.5	117.43[109]	-11%
CO26	No. of enterprises cooperating with research institutions	10	30	127	+323%
CO41	No. of enterprises participating in cross-border, transnational or interregional research projects	10	30	127	+323%
CO42	No. of research institutions participating in cross-border, transnational or interregional research projects	5	5	5	-

The project partnership noted the following:

- The number of enterprises receiving grants (CO02) was lower (N=4) than the target (of 8 enterprises) as the Knowledge Exchange placements were delayed by Covid-19 and there was also limited enthusiasm from industry (and the PhD students); and
- The project's reporting of 'new researchers in supported entities' (CO24) was behind schedule, with November 2021 being the most recently available number at the time of consultation (April 2022).

[108] Source: Discussion with Project Partnership.
[109] As of November 2021 as reporting was behind schedule.

9.4.5 Key Achievements (to April 2022)

Discussion with the project partners indicates that they consider the following to be amongst the Bryden Centre project's key achievements (as of April 2022):

- The Bryden Centre played a central role in the coordination of the development of a hydrogen economy in NI, including in the development of a Hydrogen consortium in the North West set up to exploit the potential for green hydrogen.
- The Bryden Centre is involved in the All-Island Climate and Biodiversity Research Network (AICBRN) which is a major initiative bringing together leading research centres across the whole island of Ireland to tackle the climate and biodiversity emergency where a cross-border approach is essential. Researchers from all the centres across the network have come together to work with national, regional and local governments, communities and industry to effectively deliver solutions to climate, biodiversity and social challenges caused by global warming, and QUB has been critical in coordinating this. The network is exploring potential funding opportunities.
- The project received 64 applications for project proposals. The project partnership outlined that 36 projects commenced, however as 5 PhD students left early these were not completed, and a summary of the 31 project titles is provided in Appendix XVI.
- In addition, the project partnership highlighted that four PDRA positions were created at QUB[110] to work in the North-West area across the Northern Ireland/Ireland border area (including LYIT) to support the development of green-hydrogen and local industry.
- The project partnership outlined the following concerning the PhD students, as of April 2022:

  - 4 PhDs awarded;
  - 11 thesis submitted;
  - 16 PhD projects were ongoing, whilst most are due to end by June, some will have to continue beyond the end of the project.

- In addition, the project partnership outlined that 4 students were involved in ongoing (at the time of consultation, April 2022) Knowledge Exchange placements, 3 were employed in academic institutions and 1 was employed in industry.
- The feasibility study work aspect of the project was delayed due to issues faced in recruiting Post-Doctoral Researchers, however, the Scientific and Commercial Advisory Panel and Centre Director worked together to ensure that the research aims of the Bryden Centre were aligned from an academic and industry perspective. Feasibility support was provided as follows:

  - UHI worked with Marine Scotland to consider the marine life collision risk around turbines using real-world data;
  - QUB completed a feasibility study on Killough harbour, which was presented at the EWTEC 2021 conference and was well received; and
  - QUB, with EMEC, developed a case study on tidal energy.

- The Bryden Centre evolved to look holistically at the problems concerning the circular economy, net zero and a systems-based approach.
- The project identified an opportunity to develop Killybegs as an offshore renewable energy hub, as wind energy is linked to green hydrogen production leading to ammonia production for fuel ships/fishing and export.
- The Bryden Centre supported LYIT to increase its research capacity and provided staff experience of co-supervising PhD students, this supported LYIT's development and contribution to the formation of the Atlantic Technology University.
- In Strangford/Portaferry, the project partners designed and tested tidal turbines and assessed the impact on seals and seabirds.
- The project has influenced policy concerning Clean Energy and Carbon Capture.

[110] The positions were at QUB rather than LYIT as it had proved difficult to recruit into LYIT.

- Following on from the research undertaken as part of the project, the Bryden Centre in conjunction with local industry, has been awarded c£1.8 million to support local industry, agriculture and communities, examples of projects include:

  - £620k from the Community Renewal Fund - Zero Carbon Cooperative Innovation and Developing Entrepreneurship for a New Tomorrow (0CCIDENT);
  - £490k was awarded through the Red Diesel Replacement competition run by the Department for Business, Energy & Industrial Strategy which aims to accelerate the commercialisation of low-carbon red diesel alternatives.

- The Bryden Centre ran the Bryden Summer School for PhD students which involved workshops and psychometric tests, and also the opportunity to collaborate and network with one another.
- The project partnership highlighted that the main impact on the academic institutions involved was providing the opportunity to gain experience supervising PhD students.
- The Bryden Centre academics and students attended a range of conferences, for example:

  - Engineering the Energy Transition Conference;
  - TEDxQUB;
  - All Energy Exhibition and Conference.

- The Bryden Centre also hosted/organised several conferences, including for example:

  - Carbon Capture, Utilisation and Storage Potential in Northern Ireland Seminar
  - Environment Interactions of Marine Renewables 2020 - This biennial series brings together researchers from across the Natural and Social Sciences with industry and other interested stakeholders, to explore marine renewable energy technology interactions with the environment.

9.4.6 Progress towards the Project's Stated Objectives

As reflected in Section 9.2, the Bryden Centre's Letter of Offer identified five specific project's objectives. Whilst the Bryden Centre project's progress reports did not require the project to monitor the extent to which the project was achieving each of the objectives, the Evaluation Team's discussions with the project partnership indicates the following:

Table 9.6: Project's Specific Objectives

Specific Objective	Commentary per the Evaluation Team's discussions with the Bryden Centre project
1. A platform to enable cross-jurisdictional academic and industry collaboration.	The Bryden Centre project created a 'virtual competence centre' to support industry-led applied/pre-commercial collaborative research (at Technology Readiness Levels - TRLs 2-6) on a cross-border, interregional basis. The project partnership outlined that the research projects involved industry sponsors, and this provided those businesses involved access to the wider academic community to enable collaboration and in order to support their R&I activities and capacity. As of April 2022, the project had recruited 36 PhD students and 13 PDRAs[111], which incorporated 117.43 years' (at November 2021) of PhD input (see output indicator CO24). The achievement of the objectives is evidenced by the range of project output indicators (see Table 9.5).
2. 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 to enhance industry competitiveness in a global marketplace.	
3. Bridge the gap between scientific and commercial innovation at TRLs 2-6, providing a pathway to commercialisation.	
4. Provide a critical mass of researchers and pool cross-disciplinary industrial and academic knowledge and complementary capabilities and facilitate knowledge exchange across jurisdictional boundaries.	
5. Create new knowledge to foster competencies in the deployment and development of renewable energy technologies.	

[111] However 5 PhD students and 2 PDRAs resigned/finished early due to health, financial or other personal reasons.

9.4.7 Progress towards the Project's Result Indicator Targets

It was anticipated that the Bryden Centre project would contribute to the target of 75 peer-reviewed journal and conference publications per annum through the development of 68 peer-reviewed journal and conference publications within the Renewable Energy sector with cross-border-authorship and with the potential to create economic impact.

As of April 2022, the project had 88 papers published/accepted, 20 of which had cross-border authorship. In addition, the project partnership outlined that an additional 40 papers were in the pipeline.

Table 9.7: Progress towards the Results Indicator

Result Indicator	Programme Target (annual)	Bryden Centre Project Target	Progress as of April 2022[112]
No. of peer-reviewed journal and conference publications with cross-border authorship	75	68	20[113]

Concerning the cross-border focus of the target, the project partnership highlighted that as LYIT was not a research intensive institution and had limited capacity to co-author cross-border publications, it was unlikely that the project would achieve the target.

9.5 Best Practice and Learning

This section considers whether the Bryden Centre project has resulted in any areas of best practice and learning.

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

- **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 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.
- **Influencing policy** - The project influenced planning policy in the marine environment, with research cited in Marine Alliance for Science and Technology Scotland publication 'Using marine planning to balance competing demands on the marine environment: International comparisons'.

9.6 Effectiveness of Cross-Border Working and Partnership Working

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

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

Whilst a variety of discussions and indeed some activity had been taken forward (before 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 had been, small scale and piecemeal (as a result of jurisdiction-driven funding restrictions and market failure). However, following early indications that

[112] Source: Discussion with Project Partnership.
[113] Albeit in total 88 papers were published/accepted.

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 co-operation;
- 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 co-operation;
- 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 considered that extensive technical know-how and market activity was available within the eligible region relating to marine and bio-energy, but that it was fragmented at both academic and industry level. Bryden was, therefore, serving to facilitate co-operation and partnership based on mutual exchange of knowledge and experiences that were anticipated to lead to a final result that differed qualitatively from the sum of the pre-existing activities undertaken at the level of the three jurisdictions.

The project partners note that Bryden provided the setting for interaction that would not occur in its absence, co-operation that goes beyond local, regional or even national interests and facilitated the development of synergies at the level of the cross-border/interregional territory and the achievement of a series of shared objectives.

The project partnership considers that the key added value of the cross-border collaboration involved in the project was the resulting partnerships and all-Island approach emanating from the project.

The project partnership outlined that the project did not interact to any great extent with the other project funded under the INTERREG Research and Innovation Measure, however, project partners did attend conferences/workshops that these projects also would have attended, for example, the Bryden Centre, Renewable Engine and Spire 2 were showcased during the Engineering the Energy Transition conference, held in February 2020. The conference entailed 114 leading academics, industry professionals and senior civil servants spending two days learning from a diverse range of speakers from across Europe. Research, government and industry perspectives were shared on many of the technology options, operating landscape and potential opportunities for energy transition away from fossil fuels to renewable energy. In addition, several PhD students from the Renewable Engine project attended the Bryden Centre Summer School which served to (inter alia) enhance the levels of industry engagements, provide an overview of the project's research and capabilities.

9.7 Impact on Business and Industry

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

Whilst it was anticipated that the PhD level graduates would take up short-term employment through Knowledge Exchange placements with an industrial partner to support the translation and embedding of innovative technology or practices into their business, these were delayed by Covid-19 and there was also limited enthusiasm from industry to participate. In total, seven applications were received from industry, one of which withdrew as the funding was not to be provided upfront, instead, it was to be a payment in arrears (following completion of the KE placement), with only four ultimately receiving PhD level graduate placements. An overview of the four knowledge exchange placements is provided below.

Table 9.8: Overview of Knowledge Exchange Placements

Industrial Partner	Proposal Title
AstonECO Management Ltd	Research, develop and demonstrate an Online and Mobile Centre of Excellence in Earning Local Support for Energy Projects throughout the island of Ireland, and further afield as appropriate.
Pure Marine Gen	DUO wave power for blue economy
Aquatera Ltd.	GIS Dashboards and Network Analysis for Marine Renewable Energy
Gavin and Doherty Geosolutions Ltd.	SEASAM Automation

In hindsight the project partnership considered that whilst the KE placements were a ‘nice idea’, students are not interested in short-term employment opportunities towards the end of their PhD, as most students are, in their view, keen to find full-time employment.

The project partnership outlined that there was potential for 2 IP disclosures, with a short-term PDRA employed (which started in January 2022) to develop IP originating from student projects.

The project partnership outlined that as the research projects involved industry sponsors this provided those businesses involved access to the wider academic community to support their R&I activities and capacity. The project partnership 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 whom will ultimately work in an industry in the future;
- 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.

In addition, the project partnership outlined the following examples of the impact on industry:

- The project supported a County Down-based AD plant operator to work with Rolls Royce Power Systems on a carbon capture and utilisation project for the Biomethanisation of CO2 a by-product in the production of biogas. The facility uses green hydrogen to produce biomethane for Rolls Royce Power Systems to fuel their heavy engines;
- The project provided support to major regional manufacturers including Encirc to decarbonise production through innovative use of bioenergy for furnace heat and biofuels for transport;
- The project provided help for regional companies including Colloide and Elmgrove to create new jobs which develop Nature-based solutions creating added value products from agriculture waste while reducing, ammonia emissions and excessive pollution – diversifying income streams for farmers.

- The project has continued to support industry to secure follow on funding (of c.£1.8m as of April 2022).

Furthermore, the project partnership noted that the research undertaken has been published and is publicly available for businesses and other stakeholders to take and use in their investment plans.

It is noted 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 several 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.

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

9.8.1 EU Cohesion Policy and EU2020 Objectives

The Bryden Centre project has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and supporting the shift towards a low-carbon economy.

Furthermore, the Bryden Centre project has helped to contribute to the key priority SMART Growth: Developing an economy based on knowledge and innovation identified within the Europe 2020 Strategy for Growth.

9.8.2 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) were overtly focused on developing offshore energy generating technologies and hence has contributed 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.

9.8.3 The Horizontal Principles

The Bryden Centre project partners consider that the project has contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	By focusing on the development of Advanced Marine and Bio-Energy, Bryden sought to identify methods to allow society to better live within its environmental limits and thus sought to address the many negative consequences that not doing so creates, such as climate change. However, Bryden's focus was broader than just the environment. It was also about ensuring a strong, healthy and just society within the eligible region. As well as technology-focused projects, the Bryden project partners supported socio-economic focused projects which aimed to ensure that marine and bio-energy projects met the diverse needs of all people in existing and future communities, helped to promote personal wellbeing, social cohesion and

	inclusion, and had the potential to create equal opportunity, particularly in isolated rural areas. They suggest, for example, that the marine energy sector was clearly a socio-technical system, which faced major interrelated socio-economic and regulatory challenges, in addition to a need for technical innovation. Non-technical challenges included 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. Bryden projects directly sought to ensure that the development of Advanced Marine and Bio-Energy within the eligible region balance social, economic and environmental aspects. Bryden recognised that much of the region's potential marine and bio-energy activity occurs in rural and isolated coastal areas. Bryden therefore actively explored how the development of these technologies and renewable energy sources could help provide employment (either through self-employment or through investment into the area), prosperity and opportunities through participative systems and structures that would engage both businesses and local communities (perhaps through the development of social enterprises to become supply chain partners), and which incorporated 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).
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 sought to ensure that it robustly promoted equality of opportunity between men and women and did 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 considered that there was no differential impact on any of the groups listed. A programme-specific equal opportunities policy was developed to ensure that each project partner complied with its equality obligations under anti-discrimination law. This benefited both Bryden staff and PhD students. QUB and the Centre Director were responsible for ensuring that all aspects of the policy were complied with, addressing any complaints that arose, and for monitoring and reviewing its implementation. The Project Partners took 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 involved in assessing candidates for recruitment or promotion were trained in non-discriminatory selection techniques; • Incorporating equal opportunities notices into general communications practices (e.g. staff newsletters); • Ensuring that adequate resources were made available to fulfil the objectives of the policy.
Equality between men and women	Bryden sought to ensure that it robustly promoted equality of opportunity between genders. The Project Partners ensured that both women and men had equal rights, responsibilities and opportunities in all areas of the Centre's activities. They were afforded equal opportunities for occupational achievement and advancement. In order to promote equality, the Project Partners had, with due regard to the available resources and other relevant factors:

	• Acted so that both women and men applied for vacancies. Centre publicity ensured to convey that it was 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 were suggested to have been fair and founded on the principle of objectively selecting the best person for the job; • 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 introduced an anti-harassment and bullying policy. • Complaints of discrimination and harassment were dealt with promptly and seriously. All employees, but especially those with supervisory responsibility and those who made recruitment and selection decisions, were familiar with equal opportunities principles and with Bryden's policies and procedures. The project partners stated that the policy was 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 was taken, where appropriate e.g. where the analysis of monitoring data revealed that certain groups were under-represented in the workforce/PhD intake or were experiencing disadvantage compared to other groups.

9.8.4 Contribution to Other Strategies

On a national and regional basis, the table below summarises several key strategic targets which Bryden has contributed toward achieving:

Table 9.9: Bryden Project Contribution to Other Strategies

	Strategy	Targets which 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 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

Table 9.9: Bryden Project Contribution to Other Strategies		
	Strategy	**Targets which Bryden has the potential to contribute towards:**
		• 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

In summary, the Evaluation Team is of the view that the Bryden Centre project has contributed to a range of strategic imperatives that exist across the eligible region.

9.9 Barriers to Cross-Border Co-operation

This section considers whether the Bryden Centre project has encountered any barriers to cross-border co-operation that the priority axis is not addressing. Specific issues identified included:

- State aid rules relating to the provision of financial support to businesses had, 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.

9.10 Potential Legacy Impacts

The Bryden Centre Project Partnership consider that the project has the potential to achieve a variety of legacy impacts beyond the lifetime of the project.

The project partnership outlined that there will be a legacy of the trained PhDs in the field. In addition, the partnerships developed as part of the Bryden Centre will continue and aim to raise additional funding to continue research in the area. The project partners have already secured follow on funding to continue research in the area. For example, the Bryden Centre/QUB was awarded £620k from the UK's Community Renewal Fund for the Zero Carbon Cooperative Innovation and Developing Entrepreneurship for a New Tomorrow (0CCIDENT) project which seeks to maximise the value of naturally and regionally sequestered/farmed carbon and where the businesses and communities (urban, rural, farming) which support and supply them are direct or indirect beneficiaries.

The Bryden Centre project suggests that it has influenced policy in the following ways:

- A major report (launched in an online seminar in June 2021) from the Bryden Centre investigated the options, opportunities, and economic impact for NI to decarbonise using Carbon Capture, Utilisation and Storage technologies;
- The Bryden Centre and the Centre for Advanced Sustainable Energy (CASE) responded to a paper from the Department for the Economy in NI with a focused report showing how green, renewable energy could make a substantial difference to the region. The report, 'Clean Energy – A positive future for Northern Ireland building on our strengths', presents easy and simple options together with 'shovel-ready' projects in NI that can help rebuild and expand the regional economy, helping NI to become leaders in renewable energy and green industry sectors.
- The Bryden Centre is involved in the All-Island Climate and Biodiversity Research Network (AICBRN).

The project has also influenced planning policy in the marine environment, research cited in Marine Alliance for Science and Technology Scotland publication 'Using marine planning to balance competing demands on the marine environment: International comparisons'.

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

10.2.1 Rationale for the Project

It was recognised that there was too few innovation-active SMEs in the eligible region. This was recognised in the economic and innovation strategies for the different parts of the region[114], which identified 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 persisted. In each of the three jurisdictions – Scotland, Northern Ireland and Ireland – targets had 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 Co-operation Programme sets out the need to increase the number of innovation-active SMEs in the eligible region, assess and improve their capacity, and 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 suggested that the key constraints on SME innovation were capability deficiencies in firms and the challenge of managing connectivity to the broader R&I ecosystem. Their research[115] indicated that SMEs across the region, particularly smaller ones, tended to draw on their own resources when innovating, and when they adopted a more open approach, they tended 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 aimed to facilitate and support cross-border connectivity between enterprises and research institutes.

10.2.2 Project Partners

The Programme brought 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, had a unique track record in designing, developing, delivering, monitoring and evaluating effective and efficient cross-border R&I programmes for SMEs. The other partners were:

- Scottish Enterprise and Highlands and Islands Enterprise, Scotland's economic development agencies;

[114] DJEI, Enterprise 2025; DETI, Northern Ireland Innovation Strategy, 2014-2025; Scottish Enterprise, Innovation Strategy, 2015-2018
[115] InterTradeIreland, Leveraging the Innovation Ecosystem for Business Advantage: A Cross-Border Study, December 2012

- 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), brought experience in the financial management of EU-funded programmes.

10.2.3 Project Overview, Objectives and Activities

Using its knowledge and experience in developing innovation capabilities and collaborative opportunities for SMEs, the Co-Innovate project partnership developed an integrated programme that included:

- 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 was unique in that it provided an integrated pathway to address capability deficiencies through audit-based mentoring and advice before facilitating new cross-border connections.

It was anticipated that the programme would help SMEs identify and understand the barriers that constrain their innovation activity thus limiting their growth potential. The programme worked with the firms to identify their capability deficiencies and to point them to the most appropriate supports – which could have been 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, represented 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. Concerning this aspect, both Enterprise Ireland and Invest NI agreed to establish an Advisory Board to ensure that enterprises were directed to the most relevant supports available and to avoid duplication. In Scotland, Highland and Islands Enterprise and Scottish Enterprise were the Scottish Government's agencies with responsibility for delivering business support, including all R&I supports, to SMEs. These agencies were also represented on the Advisory Board to ensure a coordinated approach that aligned the Co-Innovate Programme with existing supports.

It was anticipated that SMEs participating in the Co-Innovate Programme would:

- 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.

It was anticipated that the Co-Innovate Programme would focus on SMEs from manufacturing and tradable services, with specific priority afforded to enterprises from the Renewables, HLS and Agri-food sectors.

The project was delivered in five strands, as illustrated in Table 10.1 and Figure 10.1.

Table 10.1: Overview of the Co-Innovate Programme	
Strand	**Description, Anticipated Outputs and Targets**
1. Innovation Ready Reckoner and Workshops	'Strand one' was the primary recruitment opportunity for SMEs to the programme. It acted as the initial 'gateway' for most SMEs to participate on the initial and subsequent strands and hence was considered to be the most important stage in the process. In Strand 1, it was anticipated that 1,408 SMEs would be recruited onto the programme. Concurrent with the recruitment of businesses, it was envisaged that 108 R&I workshops would be delivered across the eligible region ensuring equality of access for SMEs, with each attended by up to 30 SMEs. The project partners proposed that participant SMEs would be drawn from the manufacturing and tradeable services sectors. SMEs were 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 have demonstrated some level of innovation capability, this initial engagement included a preliminary innovation diagnostic/assessment (use of the Innovation Ready Reckoner – IRR[116]), capture of sufficient baseline data and completion of an online application form, which enabled shortlisting of the most suitable SMEs. It was envisaged that the completion of the IRR would ensure that as many SMEs as possible would benefit from some form of innovation 'takeaway' regardless of how far they progressed on the programme. The IRR aimed to capture high-level data including the extent to which the SME already innovated, the quantum of innovation, use of knowledge and technology, idea management and implementation, leadership and culture. Delivery of this aspect was 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 was envisaged that the 1,408 shortlisted SMEs would 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 would be engaged with pre workshops and both natural attrition and shortlisting would ensure than only the most suitable SMEs progressed to a workshop. It was proposed that each workshop would run for a half-day with attendees receiving useful collateral to take away and study. The workshops aimed 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 was actively promoted to encourage peer to peer networking among like-minded SMEs and sharing lessons learned from innovation case studies. The project partners recognised that the main risk associated with the project was the recruitment of sufficient quality of SMEs to progress to later strands i.e. SMEs who had the financial capacity and desire to invest in later strands. However, the project partners proposed that their experience and robust recruitment plan would mitigate this risk, alongside the implementation of a rigorous 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.

[116] 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**
2. Business Status Review and Innovation Audit	'Strand two' of the programme was a series of one-to-one innovation interventions offered to SMEs who had been shortlisted or expressed an interest in progressing after their participation in strand one. SMEs that participated on strand one would now be aware of the benefits of embracing and utilising innovation to help grow their business and they would have a wider understanding of the local and cross-border innovation ecosystem. This strand was an opportunity to work with the SME on a one-to-one intensive basis to explore further areas for growth with innovation. SMEs who progressed successfully from the workshop to Strand 2 availed of a Business Status Review which explored amongst other things existing and potential export opportunities. The Innovation Audit undertaken identified 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 was to identify those SMEs from strand one workshop attendees with potential to progress to a more intensive innovation activity, the innovation audit. It was anticipated that 1,200 SMEs (85% of 1,408) that attended strand one workshops would express an interest in progressing to strand two and each of these SMEs would 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 assessed in detail the SME's underlying business issues which may/may not hinder their ability to fully embrace innovation. It was anticipated that the BSR (with recommendations) would take two days per SME to complete. The proposed breakdown of BSRs across the eligible region was NI 595 (50%), Ireland 306 (25%), Scotland 299 (25%). After carrying out the BSR, the expert made a recommendation on suitability to progress (or not) and following approval by the assessment panel 520 SMEs were to progress to the innovation audit stage. It was anticipated that, following natural attrition, 469 would 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 was NI 232 (50%), Ireland 119 (25%), Scotland 118 (25%). The in-company innovation audit considered the findings of the Innovation Ready Reckoner completed in strand one and the BSR and subsequently identified capability deficiencies, strengths, needs and opportunities for research and innovation. The documented outcome included preparation of a bespoke innovation action plan which would address capability deficiencies and opportunities for innovation that could 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 was anticipated that the Innovation Audit would 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 was envisaged that a key element of undertaking the innovation audit would be the full engagement of the CEO or senior management team. This level of engagement was considered crucial at this stage and stemmed from the lead partner's experience of similar interventions. Further time allocation had been factored in for a transition to the next stage/audit interpretation meeting. This meeting involved 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 was to ensure the SME (and local contact if appropriate) understood the results of the audit, provided an opportunity for personalised signposting to other innovation supports and how these could be built on to ensure there were legacy benefits in place once the SME's participation in the formal programme came to an end. This stage was particularly important for SMEs who did not progress to later strands of the programme. This stage also ensured that SMEs drawn from the target sectors of life and health sciences and renewable were made aware of the opportunities that existed 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 was an intensive in-house innovation capability building programme. The purpose of this work package was to assist SMEs to improve their innovation capabilities in order to more effectively engage in collaborative cross-border research and innovation partnerships. Tailored support was provided to SMEs in the form of technical and innovation expertise (academic or consultant), drawn from a procured framework, who worked intensively with the participating SME. The value of the support was capped initially at €7,000 per SME and would deliver approximately 10 days support over a 5-month period.

Table 10.1: Overview of the Co-Innovate Programme	
Strand	**Description, Anticipated Outputs and Targets**
	Based on the project partners' experience of delivering similar programmes, an attrition rate of 15% was anticipated. Therefore, a total of 110 SMEs were anticipated to be approved by the assessment panel to progress onto Strand 3 with the expectation that 94 would complete. In the previous strand, 469 SMEs were to receive an innovation audit. From this, a report was to 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, would contain recommendations on how best the SME should be signposted to progress through the Co-Innovate Programme. This may have been a recommendation to progress to strand 3, to strand 4 or 5 or an alternative option. It was expected that where reports identified specific capability deficiencies that were impeding the potential to collaborate and innovate, participation in Strand 3 would be recommended. In this instance, the report was to be reviewed by the Co-Innovate assessment panel, at their bi-monthly meetings, who would consider the recommendation and either approve or reject the progression. The innovation audit report would 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 was open to consultants and academic experts, would provide the participating SMEs with access to the very best available technical and innovation expertise that would impact their innovation capability and their prospects of engaging in a cross-border collaborative R&I project. When SMEs were approved by the assessment panel onto Strand 3, they would be matched with the most suitable expert from the procured framework. The lead partner would be responsible for the initial shortlisting of suitable experts from the framework, from which a mini-competition would identify the optimum expert. All SMEs would be assigned to a local member of the programme delivery team. These would be involved in the mini-competition to identify the best expert for the SME. They would be responsible for coordinating and overseeing the engagement between the SME and the expert and ensuring delivery of outputs against targets and timeframe. They would also act as an honest broker to handle queries and address delivery challenges. At the conclusion of Strand 3, the programme delivery team would assist SMEs with the progression to either strand 4, strand 5 or alternative supports across the eligible area.
4. Cross-Border Innovation Internship Programme	Strand 4 matched SMEs with an academic or researcher (provided by an academic institution or research institute registered on a procured framework). These partners then worked together to develop a 12-month work plan resulting in new product, process or service development. The SME was 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. While these projects were 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 was 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 had the need and potential to take part in Strand 4 would be assessed and approved by the Strand Manager and then circulated to the Technology Transfer Offices (TTOs) of Academic Institutions on the framework. It was anticipated that 70 SMEs (27 in Northern Ireland; 26 in Ireland; 17 in Scotland) would subsequently engage a graduate to undertake a 12-month cross-border research project in partnership with an academic/research institution. It was noted that the project partners had proposed that to ensure 70 completions, 115 applications would be presented to the Assessment Panel, 105 projects would be approved, with 80 projects planned to start. The Academic Lead(s) were 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 were 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.

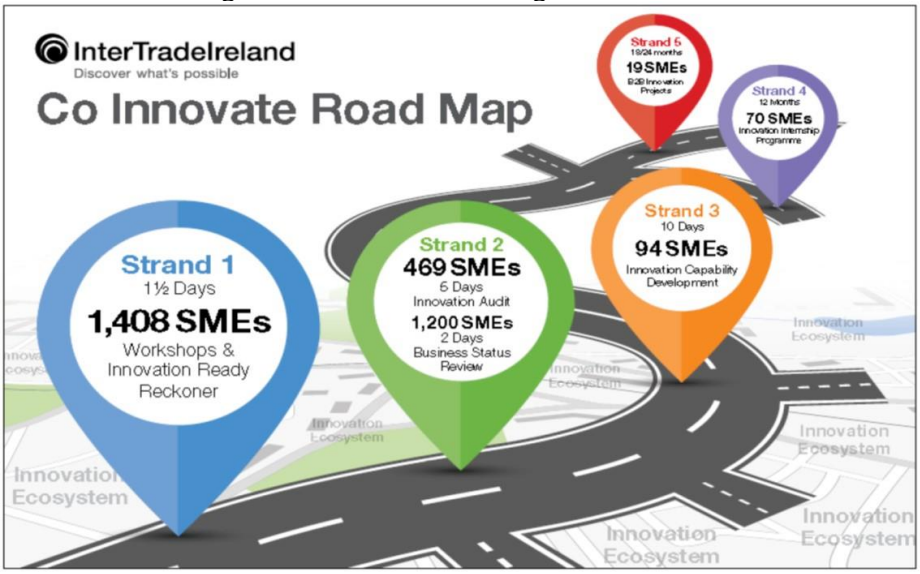
Table 10.1: Overview of the Co-Innovate Programme	
Strand	**Description, Anticipated Outputs and Targets**
	• Develop the company's knowledge and capabilities while embedding innovation for the future. • Accelerate the development of their product/service/ process to drive their businesses' competitive advantage and boost their bottom line. • Benefit from the additional dedicated support the Project Manager would 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 would submit their Expression of Interest, through their TTO, to the Strand Manager who would 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 would be held involving the SME, academic and Programme Delivery Team staff to ensure agreement on the way forward for the project partnership. This meeting was 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 would then take the lead in preparing an application form for assessment by the full Programme Assessment Panel. This form would 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 would review the most recent financial accounts information for the SME and would liaise with other Business Development Agencies to ensure there was no double funding or any other issues of concern. Programme Delivery Team staff would manage the process of feedback to successful and unsuccessful applicants and would manage the re-application process if required. For successful applicants, Programme Delivery Team staff would manage the process of attracting graduates, posting jobs on appropriate websites and ensuring the shortlisting and interview process was 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 would also support SMEs and academics through the financial claims process and ensure that a comprehensive final report capturing the benefits and learnings was submitted. The project partners note that during the project and following completion, as there was a programme focus on the key sectors of Renewables and Life and Health Sciences, it would be key to ensure all relevant SMEs were advised of the opportunities available within Investment priority 1A. The Programme Delivery Team would work closely with all relevant partners to promote collaborative R&I opportunities.
5. R&I Partnerships	The objective of Strand 5 was 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[117]; and • 4 innovation network/cluster projects – which would 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 were Renewables, Life and Health Sciences, Agri-food and one market opportunity driven network. It was

[117] 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**
	anticipated that each of the 4 network projects would 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 would 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 was a focus in this stage in establishing network projects in the Life & Health Sciences, Renewable Energy, and Agri-Food sectors, but the programme was not limited to these areas only. The Programme offered: • Up to €7,000 funding for resources to complete a feasibility study and a full business plan application for the R&I project. • Grant per business to a business partnership of up to a maximum 50% eligible funding capped at €150,000. Co-Innovate was 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 was supported by the Co-Innovate programme would involve a group of companies and at least one academic partner (a minimum of three business organisations and one academic institute). Funding provided would be for a very specific purpose and the results of the cluster activity would have some identifiable and measurable impacts for each partner. Specifically, a business network was likely to result in an enhanced competitive advantage and/or mutual financial gain. The type of SME to be engaged would be one that had significant export scale potential and had the absorptive capacity to undertake a collaborative R&I project. The 15 business to business partnerships would receive grant assistance for cooperative R&I activity. This Strand would focus on priority areas of Life and Health Sciences, Renewable Energy, and Agri-Food. Other anticipated outputs included 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) would focus on those SMEs completing Innovation Audits (Stage 2) who were recommended as best able to undertake collaborative research and innovation activity. A rigorous collaborative development process would be undertaken. The Programme Development Team would be instrumental in raising awareness, particularly among the highlighted sectors of Renewables, Life and Health Sciences and Agri-Food. The specific process would 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 would 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 would 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 could have included Technology Transfer Offices at Universities, Colleges and other academic centres. The team would 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.

Table 10.1: Overview of the Co-Innovate Programme	
Strand	**Description, Anticipated Outputs and Targets**
	The Programme Delivery Team would prepare the full business plans for presentation to the Assessment Panel. Each submitted plan would be subject to an independent assessment from a publicly procured panel of Technical and commercial specialists. Only applications which received a positive recommendation from the external assessors would be recommended for support. It was envisaged that this would reduce the risk of lower-quality applications being considered. A dedicated member of the Programme Delivery Team would be assigned to each successful application. This would ensure continuity through the assessment and delivery process. Programme staff would provide feedback decisions to all assessed applications, including those unsuccessful. Detailed Letters of Offer would be issued to successful partnerships in accordance with agreed corporate governance. All collaborative projects would commence with an initiation meeting to agree on the project plan and project meeting timetable. The assigned Programme Delivery Team member would attend and be the contact point for all project issues. This would mitigate the risk of project slippage. Project meetings would be conducted on a quarterly basis to ensure progress was on track, any potential hurdles were addressed, claims were submitted promptly and that a plan was in place for the next quarter. A formal record of the meeting would be undertaken and agreed by each partner. This would be recorded on the dedicated Information Management Portal. Companies that participated on a Co-Innovate Business to Business Partnership were 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 participated on a Co-Innovate Cluster Partnership were 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 would 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 concerning developing prototypes; • Clinical Trials and Testing Costs.

Figure 10.1: Co-Innovate Programme Strands



To deliver the project activities, seven work plans were developed, as follows:

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

10.2.4 Anticipated Outcomes and Results

The programme aimed 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 intended to engage with over 1,408 SMEs, providing them with education, capability development and support according to need and absorptive capacity.

Ultimately, the project partners anticipated that the programme would 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.

An overview of the expected results by Strand is provided below.

Table 10.3: Overview of the Co-Innovate Programme Expected Results	
Strand	**Expected Result**
1. Innovation Ready Reckoner and Workshops	Greater awareness of the need for R&I in business and of ways to develop R&I capability
2. Business Status Review and Innovation Audit	Participant SMEs have a thorough understanding of their R&I position, and a clear action plan to achieve their aims and objectives
3. Innovation Capability Development Programme	Enhanced innovation absorptive capacity for SMEs.
4. Cross-Border Innovation Internship Programme	Jobs created, investment in human capital and the development of new products and processes
5. R&I Partnerships	Increased performance, capability and profit for SMEs; innovation networks

Ultimately, the project partners suggested that enterprises completing the programme would develop new products, processes and services and improve their growth trajectory.

10.3 Project Expenditure to July 2022

The Co-Innovate project received a Letter of Offer (dated 21st June 2017) offering a grant of up to a maximum of €16,671,744 (ERDF + Government Match Funding) to be expended and claimed by 31st March 2022, towards total anticipated project costs of €22,443,035.

In March 2020, the SEUPB approved a 6-month project extension, to 30th September 2022 and the reallocation of budget between categories, with a revised LoO issued in January 2021[118]. Furthermore, the SEUPB issued a further revised LoO (dated 1st September 2021) offering a grant of up to a maximum of €16,641,271 (ERDF + Government Match Funding) to be expended and claimed towards total anticipated project costs of €22,407,185 by 31st March 2023, representing a further 6-month extension and a reduction in the overall project budget.

Further to the above, in April 2022 SEUPB issued another revised LoO (dated 25th April 2022) offering a grant of up to a maximum of €15,883,805 (ERDF + Government Match Funding) to be expended against total project costs of €20,707,185, which reflects a reduction in the anticipated total costs for external expertise and services, which in turn reduced the overall anticipated project costs, as reflected in the table below.

The Evaluation Team's review of SEUPB's EMS indicates that as of July 2022, the project had reported total estimated expenditure of €14,655,403, equivalent to 71% of the total project budget.

Table 10.4: Project Costs – Anticipated and Estimated Actual July 2022 (€)

Summary Budget	Anticipated Total	Estimated Expenditure in July 2022[119]			
		Reported to JS by FLC	Pipeline Expenditure (excluding items deemed ineligible by FLC)	Total Estimated Expenditure	% of the total budget
Staff Costs	4,424,499	3,317,436	665,130	3,982,566	90%
Office and Administration Costs	663,660	497,606	99,751	597,356	90%
Travel and Accommodation Costs	276,152	143,010	2,429	145,439	53%
External Expertise and Services	15,232,731	4,806,408	5,014,865	9,821,272	64%
Equipment Costs	110,144	97,669	11,100	108,769	99%
Total	**20,707,185**	**8,862,129**	**5,793,274**	**14,655,403**	**71%**

[118] Dated 18th January 2021.
[119] Source: SEUPB's EMS 18th July 2022

Discussion with the Co-Innovate project partnership in June 2022 indicates that there is potential for a c.€1.88m underspend by the end of the project period, estimated as follows:

Table 10.5: Projected Expenditure and Underspend by Project End[120] (€)

Budget line	Partner Total Budget	Actual Declared to Date (Period 23 – April 2022)	Total Forecasted Expenditure (Periods 24-27)	Total Projected Expenditure to the end of the project	Potential Underspend at end of the project
Staff costs	4,424,499	3,864,419	460,093	4,324,512	99,987
Office and administration	663,660	579,965	69,000	648,966	14,694
Travel and Accommodation	276,152	144,774	11,400	156,174	119,978
External expertise and services	15,232,731	9,128,152	4,463,592	13,591,744	1,640,988
Equipment	110,144	98,325	11,100	109,425	719
Total	**20,707,185**	**13,815,635**	**5,015,185**	**18,830,820**	**1,876,365**

[120] Source: Co-Innovate Partnership, Partner budgets at 30 April 2022 (provided to the Evaluation Team in June 2022).

10.4 Key Achievements & Contribution to Priority's Specific Objectives and Result Indicators

This section considers the Co-Innovate project's key achievements 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.

10.4.1 Key Activities Undertaken (to April 2022)

The Evaluation Team's review of the Co-Innovate project partners' progress reports indicates that key activities undertaken since the second evaluation report (between February 2020 and April 2022[121]) include the following:

Table 10.6: Key Project Activities

Period	Dates	Key Activities /Points of Note
15	1st February 2020 – 30th April 2020	• Six additional SMEs were approved to start their Strand 4 projects. • Further SMEs were matched with academic partners by Helix/Interface and wrote their full project applications. • In Strand 5, 1 business was approved to begin their project work and was awaiting signed letters of offer before permission to start. Furthermore, four businesses were approved to receive up to €7k funding to develop their full project application. • The Strand 4 LEAP campaign was developed with Krow.
16	1st May 2020 - 31st July 2020	• In Strand 3 ten additional SMEs completed their innovation capability development. • Thirteen SMEs were approved to start their Strand 4 Projects and further SMEs were matched with academic partners by Helix/Interface and wrote their full project applications. • In Strand 5, three business-to-business projects were approved to begin their project work whilst two additional projects were approved to receive up to €7k funding to develop their full project application.
17	1st August 2020 – 31st October 2020	• For Strand 1, InterTradeIreland delivered three workshops in Northern Ireland and Scottish Enterprise delivered one workshop. Strand 1 activity was completed in this period and the output indicator was achieved. • Five additional projects were approved to start their Strand 4 projects but 4 exited early due to the Covid-19 impact on their business. Furthermore, another project exited due to a change in their company size to a large enterprise. • In Strand 5 a further 2 projects were approved to receive up to €7k funding to develop their full project application.
18	1st November 2020 – 31st January 2021	• Regular panel meetings to assess applications to Strand 4 were taking place. • In Strand 5 seven further businesses were approved to receive up to €7k funding to develop their full project application. • Helix continued to generate leads & support Strand 4 project applications.
19	1st February 2021 – 30th April 2021	• InterTradeIreland and Scottish partners continued to deliver workshops. • Business status reviews continued to take place, as did innovation audits. • Work relating to Strands 4 and 5 continued to progress despite experiencing issues engaging with companies and progressing project activity due to Covid-19 restrictions.

[121] Please note that the key achievements have been documented in respect to the most recent Partner Project Progress reports that were available to the Evaluation Team at the time of writing (July 2022). The most recently available collated Project Progress report for the project was for period 21 (August – October 2021) with key achievements outlined in the subsequent periods taken from partner progress reports.

Table 10.6: Key Project Activities		
Period	**Dates**	**Key Activities /Points of Note**
20	1st May 2021 – 31st July 2021	• In terms of Strand 4, 81 SMEs had projects approved with 58 having commenced project work and the balance progressing with their recruitment. • Continued to experience issues engaging with companies and progressing project activity due to COVID-19 restrictions. • Required budget modifications were submitted following approval of a 6-month extension.
21	1st August 2021 – 31st October 2021	• The Strand 3 output indicator was successfully achieved in this period with 94 SMEs (50 NI, 22 ROI, 10 Scottish Enterprise, 12 Highlands and Islands Enterprise Ltd) having completed the Capability Development Programme. • InterTradeIreland and Scottish partners continued to deliver workshops. • Business status reviews continued to take place, as did innovation audits. • Work relating to Strands 4 and 5 continued to progress despite experiencing issues engaging with companies and progressing project activity due to Covid-19 restrictions. • Recruitment and retention of project managers in strand 4 also remained challenging.
22	1st November 2021 – 31st January 2022 (From Partner Progress Reports)	• InterTradeIreland and Scottish partners continued to deliver workshops. • Business status reviews continued to take place, as did innovation audits. • Work relating to Strands 4 and 5 continued to progress despite experiencing issues engaging with companies and progressing project activity due to Covid-19 restrictions. • Recruitment and retention of project managers in strand 4 also remained challenging.
23	1st February 2022 – 30th April 2022 (From Partner Progress Reports)	• InterTradeIreland and Scottish partners continued to carry out business status reviews with 1,108 carried out in total by the end of this period (609 in NI, 286 in ROI, 116 by Scottish Enterprise (SE) and 98 by Highlands and Islands Enterprise (HIE) Ltd). • Furthermore, a total of 446 innovation audits had been completed by the end of this period (233 in NI, 107 in ROI, 47 by SE and 59 by HIE). • A further Northern Irish SME completed the Capability Development Programme under Strand 3, taking the total to 95 SMEs overall. • By the end of this period under Strand 4, 89 SMEs had projects approved to start. 39 of which had completed their projects (17 in NI, 14 in ROI, 6 with SE and 2 with HIE). In addition, there were a further 27 live projects and recruitment for the programme was complete. • Under Strand 5, 4 clusters and 15 business-to-business projects had been approved to start, consisting of 37 SMEs which exceeded the final target of 30. One project was completed in this period, bringing the total number of completed projects to three.

10.4.2 External Impact Factors

Discussion with the Project Partners indicates that the project encountered several issues during its delivery. The issues and barriers encountered included:

Impact of the Pandemic

The Evaluation Team's discussions with the Co-Innovate Project Partnership during September 2020 as part of the Interim Evaluation report identified that the pandemic and the related restrictions on the movement of people meant that:

- Various staff across the lead partner's organisation, project partners or direct beneficiaries started working remotely, were furloughed (including LEA staff, albeit none of these staff were 'full-time' on Co-innovate. The only full-time staff member that Enterprise NI has allocated to the Programme has not been furloughed), or made redundant.

- Recruitment, workshops, business status reviews, innovation audits, and mentoring had to largely be delivered remotely, which slowed progress and removed the human engagement element with the partnership considered to be preferential and beneficial.
- Facilitating cross-border collaboration and employing interns became much more difficult (which the partnership considers had been exacerbated by businesses' perceptions of potential Brexit-related risks);
- Travel and use of laboratories had been restricted;
- Strand 4 projects had, in particular, been affected, as companies' facilities were locked down so the R&D could not continue in many cases. Furthermore, academic institutes were closed which caused issues accessing the academic lead or university facilities. The project reports that it had also been difficult to hold recruitment drives or interviews to recruit Interns. Indeed, many companies were not in a position to employ a new Intern as staff while they furloughed or laid-off existing staff.

Ultimately, as outlined in Section 9.3, to allow the Co-Innovate project further scope and time to progress its planned activities, the project received a six-month extension[122] to the project to 31st March 2023.[123]

During April/May 2022, the project partnership outlined the following concerning Covid-19:

- The restrictions imposed due to the Covid-19 pandemic have impacted the delivery of each Strand to varying degrees since March 2020. Businesses could not collaborate with other businesses or academic institutes easily remotely, this was especially challenging cross-border with travel/ distance restrictions, company facilities / academic laboratories were inaccessible, and staff were furloughed, etc.
- As a result of the Covid-19 Pandemic, all staff working on the project had to revert to remote working almost overnight. This caused some challenges in respect of the financial verification of expenditure as documentation could not be verified at Partners premises and everything had to be verified online. This did take a period of adjustment by all staff, but everyone adjusted well and new procedures and processes were established that ensured that no claims deadlines were missed.
- All Partners ensured that samples for SEUPB were uploaded in a timely manner, and no deadlines were missed. However, *"since the onset of the Covid-19 Pandemic payments from SEUPB have been extremely slow and this has caused significant cash flow problems for some Partners".*

A positive outcoming was that the project partnership highlighted the group of 18 businesses that responded to the pandemic and came together to set up a not-for-profit company, Hero Shield Ltd, to repurpose their manufacturing facilities and supply chains to manufacture low-cost quality face visors for health workers with help from €300,000 of funding from the programme.

Impact of Brexit

A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Discussion with the Project Partnership indicates that the outworkings of Brexit created a range of issues including currency fluctuations, the need to change suppliers (e.g. from GB to ROI) due to delivery difficulties, inflationary cost increases and skills shortages.

In addition, during the first evaluation reporting period, consultation with the Project Partner's indicated that there were delays in approving Strand 4 and 5 projects due to the uncertainties that existed amongst the business community in the eligible region concerning the potential impact of the UK's withdrawal from the EU (i.e. 'Brexit'). It is understood that several businesses expressed reservations to commit funds and resources which may have been required to address emerging needs following Brexit. It was

[122] In addition, just before the onset of the Covid-19 pandemic SEUPB had approved a 6-month project extension, to 30th September 2022.
[123] To facilitate the completion of the Final Evaluation report within SEUPB's required timeframe, discussions with the project partnership were undertaken during April/May 2022, meaning that the project continued to have circa 11 months before it was anticipated to complete.

suggested that this issue was more pronounced for those businesses that engaged in relatively lower levels of Brexit planning/preparatory activities;

Other Factors

Other issues included:

- **Delays in businesses progression along the Co-Innovate support funnel due to Strand 2 'bottlenecks'**- During consultation, the Project Partners (during the report 1 period) 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 noted that the actual timeframes were between 6 and 8 weeks. In retrospect, the Project Partners suggested that it would have been beneficial to merge the two assessments into one to expedite the process and the bureaucracy placed on businesses;

- **Delivery of Programme activity in the Highlands and Island's area of the eligible region** – During the first evaluation consultation process, the Project's Partners noted that levels of activity in the Highlands and Island's area were 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 Highlands and Island's area by two Programme managers (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 Highlands 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 several financial claims that have been submitted to SEUPB. It was noted that this inadvertently created delays in the payment of external experts (e.g. mentors) who have subsequently expressed concern about engaging with the Programme further.

The project partnership highlighted the agility of the businesses involved in the Co-Innovate Programme in terms of their ability to respond and adapt to all of the challenges over the last number of years (Brexit, Covid-19, and the war in Ukraine).

10.4.3 Progress towards the Project's Output Indicators

As of April 2022, the project had achieved all of the project indicators except for the targeted number of enterprises:

- Receiving one-to-one innovation advice (linked to Strand 2); and
- Engaging an innovation intern, on a cross-border basis (linked to Strand 4).

Table 10.7: Progress towards the Co-Innovate Output Targets

Output Code	Description	Programme Targets	Co-Innovate Target	Actual (As of April 2022[124])	Variance against project target
CO01	Productive Investment: Number of enterprises receiving support	1,408	1,408	1,412	-
CO02	Productive Investment: Number of enterprises receiving grants	19	30	35	+17%
CO04	Productive Investment: Number of enterprises receiving non-financial support	1,408	1,408	1,412	-
CO26	Research, Innovation: Number of enterprises cooperating with research institutions	50	50	66	+32%
CO41	Productive Investment: Number of enterprises participating in cross-border, transnational or interregional research projects	19	30	35	+17%
CO42	Productive Investment: Number of research institutions participating in cross-border, transnational or interregional research projects	5	5	5[125]	-
1.22	Number of enterprises receiving one-to-one innovation advice	469	469	447	-5%
1.23	Number of enterprises in receipt of an Innovation Capability Development Programme	94	94	97	+3%
1.24	Number of enterprises engaging an Innovation Intern	70	70	66	-6%

[124] Source: Discussion with Project Partnership.
[125] The five research institutions are participating in 8 research projects: South West College (1), Scottish Association for Marine Science (1), Dundalk Institute of Technology (2), Ulster University (2) and Queen's University Belfast (2).

10.4.4 Key Achievements

General Key Achievements

The project partnership outlined that the key achievement of the Co-Innovate Programme was the delivery of the partnership. This was the first time that the project partners had come together to deliver a programme of activities and it had to overcome competing priorities and uncontrollable market effects (Brexit, Covid-19, War) to ultimately manage consistent delivery across the jurisdictions. In addition, across the programme strands, the project partnerships highlighted the following as achievements:

- The project provided, through attendance at a workshop, 1,412 businesses with external knowledge which increased their understanding of collaborative R&D.
- Strand 4 supported the development of three-way partnerships, between industry, academia and project managers. It was highlighted that some project managers involved in Strand 4 were offered full-time employment with the industry partner and that Strand 4 connected research institutes to allow for cross-networking.
- Strand 5 introduced businesses to the benefits of cross-border collaboration, as even those projects that were not approved for support, due to timing, received introductions and knowledge.
- The sustainability projects undertaken under Strands 4 and 5 are aligned with the green agenda.

Key Achievements By Project Strand

Key achievements (at May 2022[126]) by project strand are discussed below:

Strand 1

At the end of April 2022, the target of 1,408 had been exceeded, with 1,412 SMEs attending a workshop (135 workshops) under Strand 1.

Table 10.8: Progress under Strand 1

Year	Northern Ireland		Ireland		SE		HIE		Total	
	Work shops	SMEs	Work shops	SMEs	Work shops	SMEs	Work shops	SMEs	Work shops	SMEs
Target	56	696	24	360	14	176	14	176	**108**	**1,408**
Actual (at April 2022)	64	694	27	365	29	175	15	178	**135**	**1,412**
Difference	**8**	**-2**	**3**	**5**	**15**	**-1**	**1**	**2**	**27**	**4**

Strand 2

At the end of April 2022:

- 1,108 businesses had completed a Business Status Review; and
- 447 businesses had completed an Innovation Audit.

Table 10.9: Progress under Strand 2

Strand 2	Northern Ireland		Ireland		SE		HIE		Total	
	BSR	IA	BSR	IA	BSR	IA	BSR	IA	BSR	IA
Target	595	232	306	119	150	59	149	59	**1,200**	**469**
Actual (at April 2022)	609	233	285	107	116	47	98	60	**1,108**	**447**
Difference	**14**	**1**	**-21**	**-12**	**-34**	**-12**	**-51**	**1**	**-92**	**-22**

[126] Source: Discussion with the Project Partnership.

Discussion with Co-Innovate highlighted the following concerning Strand 2:

- As a result of the regulations imposed by the COVID-19 restrictions, BSR and IA could not be delivered face-to-face with companies at their premises or elsewhere. Delivery consultants (in Ireland) and Programme Managers in Scotland were advised to deliver the assessments via telephone and online conferencing facilities where possible and appropriate. However, it was stated that some companies had proven difficult to contact.
- SE/HIE amended the BSR template to better support delivery to their client businesses.
- An email marketing campaign is ongoing, and delivery is expected to extend into Q3 2022.

The Co-Innovate Team is confident that the Strand 2 targets will be met by the end of the Programme.

Strand 3

At the end of April 2022, 97 business had completed their participation in Strand 3.

Table 10.10: Progress under Strand 3					
Strand 3	**SMEs completing the Capability Development Programme**				
	Northern Ireland	**Ireland**	**Scottish Enterprise**	**HIE**	**Total**
Target	46	24	12	12	**94**
Actual completed to April 2022	51	22	10	14	**97**
Difference	**5**	**-2**	**-2**	**2**	**3**

Discussion with Co-Innovate highlighted the following concerning Strand 3:

- Similar to Strand 2, the regulations imposed by the COVID-19 restrictions, affected the project partners' ability to deliver Strand 3 capability development activity, whereby they could not continue to deliver the face-to-face activity with businesses at their premises or elsewhere. Delivery consultants were advised to deliver the assessments via telephone and online conferencing facilities where possible and appropriate.
- SEUPB agreed (in August 2020) to allow Co-Innovate to offer more Strand 3 support by halving the number of mentoring days available from 10 to 5 days to increase the demand for Strand 2 and feed into Strand 4. However, the project partnership highlighted that as Strand 3 was ahead of schedule and had a pipeline of potential SMEs (at that time), there were ultimately no issues with achieving the full target numbers.

Strand 4

At the end of April 2022, 89 SMEs had been approved to start their project work in collaboration with an academic partner. However, 23 business projects had withdrawn, for various reasons including:

- Their appointed interns resigned from their positions for alternative permanent positions, and the company(s) did not wish to re-recruit.
- The businesses were not able to attract suitable candidates to the post, despite multiple recruitment campaigns.
- The impact of the ongoing covid restrictions locking down factories and academic partner facilities for carrying out the project work.

At the end of April, 66 projects had commenced, 39 of which are now complete.

Table 10.11: Progress under Strand 4					
Strand 4	**Innovation graduates placed in SMEs**				
	Northern Ireland	**Ireland**	**Scottish Enterprise**	**HIE**	**Total**
Target	27	26	9	8	**70**
Projects Commencing	25	25	9	7	**66**
Completed Projects (at April 2022)	17	14	6	2	**39**
Difference (commenced)	**-2**	**-1**	**-**	**-1**	**-4**

Discussion with Co-Innovate highlighted the following concerning Strand 4:

- Both Covid-19 and Brexit have contributed to slowing progress in the delivery of Strand 4. The restrictions due to the Covid-19 pandemic impacted the delivery of Strand 4, as businesses have not been able to collaborate with other businesses or academic institutes in person, travel cross-border was restricted, business facilities / academic laboratories were inaccessible, and staff were furloughed. Supply chain issues also continued to impact the speed of progress with some projects as sourcing materials remains challenging.
- In addition, recruiting interns was difficult, given the specialisms required for some roles, the buoyancy of the labour market and the added difficulty of recruiting remotely.
- The Co-Innovate Partners emphasise that they have strived and made every effort (including procuring the services of Helix to generate high-quality leads) to fully meet this target of 70 completed projects, however with ongoing COVID-19-related impacts and restrictions, some approved/pipeline projects withdrawing (and a risk that more may withdraw) and a Programme end date of March 2023, a shortfall in the Output Indicator target number for Strand 4, i.e. Indicator 1.213 "Number of enterprises engaging an Innovation Intern" (70), is likely. The project partners have advised the Evaluation Team that they are aiming to have 66 (c.94%) projects completed.

It is evident that the COVID-19 pandemic and associated restrictions had a negative impact on the programme's ability to recruit SMEs onto Strand 4, and there is a real risk that the programme will not achieve its output indicator and targets associated with this strand. However, given the circumstances (since 2020), it is the Evaluation Team's view that whilst the programme will likely not be able to reach its original target, it should be viewed positively that the programme is aiming to achieve 94% of the original Strand 4 target.

Strand 5 - Targets

At the end of April, the Co-Innovate partnership advised that 4 cluster projects and 14 Business-to-Business (B2B) projects had commenced consisting of 35 SMEs (plus 6 large businesses) and 5 unique academic institutes (involved in 8 projects).

Table 10.12: Progress under Strand 5									
	No. of Business Partnerships (lead partner)			**No. of Cluster 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
Actual Started (in April 2022)	8	3	3	2	1	1	3	1	1
Actual Completed (at April 2022)	3	0	0	1	0	0	0	0	0
Difference (started)	**2**	**-2**	**-1**	**-**	**-**	**-**	**1**	**-**	**-1**

Discussion with the Project Partners highlighted that the Strand 5 projects had been impacted (delayed) by Covid-19 and nearly all of the projects were reporting challenges in the global supply of materials and products which is impacting upon progress and drawdown of grant for projects.

Concerning Strand 5, the Co-Innovate team advised that whilst at the outset it was envisaged that the B2B projects would be easier to recruit for compared to the cluster projects, the opposite was discovered and as such the Co-Innovate team were able to combine 2 B2B projects to form a cluster project, with the following project progress overview provided to the Evaluation Team:

STRAND 5 PROJECT UPDATE

	TARGET	OUTPUT
SME PARTICIPATION	30	35
RESEARCH INSTITUTE PARTICIPATION	5	8
COMPLETE PROJECTS	14	3

Full Project Approval/Project Started			End Date
Cluster 1	NI	Shnuggle, Crossen Engineering, Ad-Vance, Denroy, XtruPak, (2 B2B Cluster)	30/09/2020
Cluster 2	NI	OHM, JMA, Mulmuf & UU (Cluster)	05/05/2022
Cluster 3	ROI	TESC, GP Developments, P. McAlister, Geda, MosArt, Setanta & UU (2 B2B Cluster)	31/07/2022
Cluster 4	HIE	Cuantec, Kilkeel Seafoods, Versatile Packaging & SAMS (Cluster)	31/07/2022
Cluster 5	RoI	Strawchip, Devine, Moy Park & SWC (Cluster)	03/09/2022
Cluster 6	NI	Statsport, Raw Stadia, RK Marketing & DKIT (Cluster)	30/09/2022
Cluster 7	SE	MicroTech, Salasq StatSports & DKIT	25/11/2022
Cluster 8	NI	Countryside, smaXtec, ANB, Devenish & QUB (2 B2B Cluster)	31/12/2022

Full Project Approval/Project Started			End Date
1 B2B	NI	Collen Bros & Wirtgen (B2B)	21/08/2021
2 B2B	NI	Irwin Carr & Crowley Engineering (B2B)	30/06/2022
3 B2B	NI	UB Solutions & Silverhill(B2B)	30/06/2022
4 B2B	ROI	Fioru & Profile Tree	30/06/2022
5 B2B	HIE	Ocean Kinetics, MMG & StorTera	31/08/2022
6 B2B	NI	Bluefield Houseboats & ICMS (B2B)	07/10/2022

10.4.5 Progress towards the Project's Result Indicator Targets

As reflected in Section 1.3.4, Specific Objective 1.2's Result Indicator and Target was to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023.[127]

The Evaluation Team notes that the number of SMEs in the eligible region greatly exceeds the number of businesses (1,408) that were anticipated to participate in the Co-Innovate Programme. As such, it would not have been possible for the Co-Innovate Programme to achieve the 11% uplift (featured in the target) in isolation. This was discussed with SEUPB and NISRA who advised that the approach adopted in setting specific Objective 1.2's Result Indicator was in line with guidance issued by the EU during March 2014 concerning monitoring and evaluation during the programme period 2014-2020.[128] The guidance document outlines the following advice:

- The intended *result* is the specific dimension of well-being and progress for people that motivates policy action, i.e. what is intended to be changed, with the contribution of the interventions designed.
- Once a result has been chosen it must be represented by appropriate measures. This can be done by identifying one or more result indicators. *Result indicators* are variables that provide information on some specific aspects of results that lend themselves to be measured.
- Different factors can drive the intended result towards or away from the desired change.
- *Outputs* are the direct products of programmes; they are intended to contribute to results;

[127] 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.

[128] Programming Period 2014-2020, Guidance Document on Monitoring and Evaluation of European Cohesion Policy, European Regional Development Fund (March 2014)

- The values of result indicators, both for baselines and at later points in time, in some cases can be obtained from national or regional statistics. In other cases, it might be necessary to carry out surveys or to use administrative data, such as registry of enterprises or unemployment benefit recipient data.
- Concerning evaluation, the guidance notes that changes in the result indicator are due to the actions co-financed by the public intervention, for example by the Funds, as well as *other factors*. In other words, the difference between the situation before and after the public intervention does *not* equal the effect of public intervention:

  Change in result indicator = contribution of intervention + contribution of other factors

As such, SEUPB and NISRA advised that the result indicator for Specific Objective 1.2 was not anticipated to measure the direct impacts of the projects supported and instead it was anticipated to measure changes in the characteristics of a given area due to programme interventions and / or other factors (i.e. external to the Interreg VA programme).

The Evaluation Team notes that c.100 SMEs engaged in research and innovation involving cross-border collaborations as a result of the Co-Innovate Programme. They were:

- The 66 enterprises that engage an innovation intern on a cross-border basis; and
- The 35 enterprises that participated in cross-border, transnational or interregional research projects.

Therefore, it is likely that the Co-Innovate Programme has made a modest contribution to the Result Indicator and Target to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023.

10.5 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 have served to 'handhold' businesses through an unfamiliar environment and safeguard monies by ensuring that businesses are questioned and challenged at each strand of support.

<u>Comments/Recommendations for SEUPB</u>

The project partnership highlighted that the SEUPB needs to be more mindful of the potential barriers to engagement for SMEs, most notably the procurement requirements. The project partnership noted that the guidance given was that purchases over £30k had to be procured via a procurement website, however, the partnership outlined that this was not possible as SMEs could not register to tender, and therefore InterTradeIreland had to take the risk to post the tenders on the SMEs behalf.

In addition, the project partnership highlighted the delays and timeliness of the payment of claims, which caused cash flow problems for some partners.

10.6 Effectiveness of Cross-Border Working 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 project's cross-border collaboration concerning the specific objectives;
- Whether any new ways of working/partnerships/relationships have been created as a result of activities carried out within the project; and
- Synergies between Projects funded.

This was a new Consortium and some of the Partners had never been involved in cross-border co-operation before, in particular, the Scottish element brought a new dimension and provided both Partners and participating companies new opportunities to learn from the Scottish Partners and share their expertise. The project partnership outlined that this was the first time that the project partners had come together to deliver a programme of activities and it had to overcome competing priorities and uncontrollable market effects (Brexit, Covid-19, War) to ultimately manage consistent delivery across the jurisdictions.

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 ensures that the proposed results and outputs will be achieved on a strategic and comprehensive cross-border basis.

Whilst the Project Partnership note that it has attended several 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. Although this may largely be because the seven projects funded under Specific Objective 1 were supporting activities focusing on earlier Technology Readiness levels (i.e. on undertaking research in the R&D&I continuum) compared to the Co-Innovate Programme being 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).The Co-Innovate partnership noted that it would have been useful to engage with the other projects working with SMEs even just to share knowledge, especially given the external factors impacting the delivery of the programme (Covid, Brexit, Ukrainian War etc).

Notwithstanding this, the Project Partners suggest that the support delivered through the Co-Innovate Programme has served to increase businesses' preparedness to engage in other collaborative R&I supports, both within and across jurisdictions, on the innovation escalator. Indeed, 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.

10.7 Impact on Business and Industry

This section considers the impact of the Co-Innovate project on business and industry within the eligible region.

The project partnership outlined that Strands 4 and 5 of the Co-Innovate programme supported businesses to engage in innovation activities on a cross-border basis (and on an interregional basis) with an academic institution and/or another business. Specifically, Strand 4 required the participating business to recruit a project manager and partner with an academic institution in a cross-border (within the eligible region) jurisdiction, and Strand 5 required a minimum of 2 businesses to collaborate on a cross-border basis, within the eligible area of the Programme.

In addition, the project partnership emphasised that earlier strands of the programme, specifically Strand 1, provided businesses with opportunities to gain an awareness of the development potential for its business in improving their capability to engage in collaborative R&I and a knowledge of how to go about it.

The project partnership outlined that industry benefits/impacts were collated in project completion reports (under Strands 3-5), however, it is not collated at a programme level. As such, the following examples of outcomes and impacts were provided[129]:

Strand 3:

- The company sought expertise on process improvement to reduce environmental impact (reduce carbon footprint), in particular, they were seeking support with green energy technology (particularly solar) to understand the level of impact it could have on the business, what an optimum green energy system could be for the business and to see if they could get to the point of having at least one fully electric vehicle on the road. The company outlined that as a result of the support provided through Strand 3 it is expected to achieve the following benefits:
  - Reduction in scope 1 emissions via the adoption of HVO fuel and EV van;
  - Reduction in scope 2 emissions by increasing PV capacity;
  - Cost savings on electricity via solar and purchasing cheaper off-peak electricity; and
  - Increased ability for a greater electrical load on-site.

- Tapa Healthcare (est. 2015) a spin-out from DKIT highlighted that Co-Innovate was an excellent way of enabling them to review all aspects of their business, focusing on innovation and future opportunities. The advice, hands-on mentoring and real-life business support provided ensure innovation, research and collaboration are embedded in their business to foster growth.

Strand 4:

- Through cross-border collaboration with an academic institute, IT Sligo, Doherty Woodshavings Ltd developed a new and improved 'one of a kind' product 'Sublime Cattle Bedding' which has been launched into the market. The business anticipates growth in sales, particularly in the cross-border market.
- Sentireal, an immersive technology company in Belfast, has developed a new innovative software platform "immersonal", in collaboration with LYIT, which enables educators and trainers to quickly and easily create their own personalised and immersive Extended Reality (XR) learning experiences for their students and clients. It enables e-Learning designers to spend their time on the core content whilst immersonal uses its Artificial Intelligence (AI) engine to automatically create an infinitely variable, personalised and engaging learning experience for their users and a detailed assessment report for the training manager. The launch of Immersonal will assist Sentireal's growth and

[129] Sources: Co-Innovate website and a sample of completion reports provided to the Evaluation Team.

expansion plans (related to sales and employment) and the strong link they have developed with LYIT creates an opportunity for further collaboration and joint ventures.

- Morgan's Fine Fish - In collaboration with the College of Agriculture, Food and Rural Enterprise (CAFRE) Loughry campus, based in Co. Tyrone, Morgan's Fine Fish has embedded a new product innovation strategy and developed a new range of healthy, valued added ready to cook products. In addition, the fish producer has enhanced their packaging to become more sustainable and consumer friendly. They have incorporated a QR code into their own branded products that link back to the company website where they have recipes and information on the sustainability of the fish.
- Viltra, a water waste Technology company based in Co. Down hired an innovation manager through Co-Innovate. Their project supported the development of a large-scale value product and created efficient manufacturing processes through 3D design.
- Cootehill, a Precision Engineering company based in Co. Cavan hired an innovation manager through Co-Innovate. The firm wanted to introduce precision 3D scanning to significantly reduce the lengthy process of reverse engineering. During their Co-Innovate project, the company partnered with the School of Engineering at Ulster University.
- WG Baird hired a designated resource to help improve the costs of defects within the business. The Project Manager introduced a new sampling process into the business.
- Ecoplastic Recycling Ltd's project developed product demonstrators of sufficient quality to quantify the potential end product performance. The product development conducted within the Co-Innovate project has the potential to play a significant role in the shaping of the company strategy, systems and services over the next 3 years. The addition of Ecogrip to the company product portfolio will serve to increase the market share within the structures and boardwalk product line. To pursue Ecogrip as a new product offering, the company will need to invest in new equipment, manufacturing processes, operating capacity and staff. The Co-Innovate project encompasses the first step in a chain of events and investments to expand the company and increase key markers such as turnover and employment.

Strand 5:

- Armagh-based Collen Bros (Quarries) Ltd collaborated with Wirtgen Ireland Ltd, based in Co. Meath to develop a system in their asphalt production plant to reduce cleaning, material wastage and production costs to enable them to offer coloured asphalt products to customers in smaller quantities and on the same day as normal black asphalts were being mixed. The project developed a rapid clean-out and change-over product enabling different colours of asphalt to be produced in a single tower plant, whilst not yet marketed the company has received interest in the product.
- Strand 5 supported a group of 18 firms to respond to the Covid-19 pandemic. The group came together to set up a not-for-profit company, Hero Shield Ltd, to manufacture low-cost quality face visors for health workers with help from €300,000 of funding from the programme. The partners who had never produced face shields before, included Northern Ireland companies Shnuggle Ltd, Crossen Engineering, Denroy Plastics, Miniprint and Ad-Vance Engineering, with support from the Queen's University of Belfast. The Irish cohort of the partnership included Xtru Pak in Cavan and Glen Dimplex in Dublin. They collectively worked to repurpose their manufacturing facilities and supply chains. Adam Murphy, CEO of Shnuggle Ltd, shared his reflections:

> *"Hero Shield was born when we heard about the desperate need for PPE. We saw an opportunity to use our collective skills and knowledge of precision engineering, plastics and manufacturing to create a low-cost, fast-manufactured face shield. We wanted these to be distributed free of charge or at cost. We will sell some products at a small profit to private companies, which will raise funds to make even more Hero Shields, allowing us to continue operating as a not-for-profit company. Funding from Co-Innovate has provided us with financial support to keep this amazing venture running for the benefit of all in society."*

- Whilst not expected, one of the businesses involved in a Strand 5 project has a PhD student working on the project, which has added weight/evidence to the student's thesis as they were able to work on an industrial scale.

In addition, the project partnership emphasised that supporting businesses to bring new products and/or new processes to market was at the core of the programme, as all Strand 4 and 5 projects were ultimately supported to develop new products and/or processes. At a high level, the project partnership outlined that each of the 39 completed Strand 4 projects had developed new products and/or processes, as follows:

Table 10.14: Overview Strand 4 New Product/Process Development		
Jurisdiction	**New products/services**	**New processes**
NI	13	4
ROI	12	2
SE	6	-
HIE	2	-

10.8 Contribution of the Project to Policy Objectives

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

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

10.8.1 EU Cohesion Policy and EU2020 Objectives

The Co-Innovate Programme has helped to contribute towards delivering the Cohesion Policy with targeted investment in key priority areas including research, technological development and innovation and enhancing the competitiveness of SMEs.

It is the Evaluation Team's view that the Co-Innovate Programme continues to offer the potential to contribute to some 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.

10.8.2 The Horizontal Principles

The Co-Innovate project partners consider that the Programme has contributed (at least in part) to the EU's three Horizontal Principles, per the following discussion:

Sustainable development	According to the project partners, the programme has, through its design, structure and outputs, positively impacted the three pillars of sustainable development, as follows: • Social equity and cohesion – The programme was 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 was promoted throughout the eligible areas in equal measure. The project partners believe that relevant SME participation and a democratic approach to selection have benefited local communities in these areas in terms of wealth creation, job creation and investment in human capital. • Economic prosperity – The programme sought to direct dedicated R&I activities and knowledge transfer to businesses in the eligible region and create enhanced research networks in areas of historical underdevelopment; and • Environmental protection - The programme actively encouraged 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.

Equal opportunities and non-discrimination	Each of the key partners is a designated public body bound by relevant equality legislation and is fully supportive and experienced in the principle of mainstreaming equality. The project partners advise that equality was 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 included 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 was noted also that an initial equality screening of the programme was carried out at its proposal stage per 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, also previously undergone formal Equality Impact Assessments (EQIAs[130]) 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 beliefs, political opinions or gender. Whilst it was 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 did 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. No potential adverse effect was identified for persons of different marital statuses or sexual orientations. The screening also suggested that the programme may promote good relations between people of different religious beliefs, political opinions and racial grouping, by bringing together individuals from different jurisdictions, institutions and backgrounds to share knowledge and experience. It was anticipated that this blending of diversity was likely to break down established barriers to co-operation and enhance learning for competitive advantage.
Equality between men and women	

10.8.3 Contribution to Other Strategies

The Co-Innovate programme delivered support for innovation that enhanced the broad innovation ecosystem while focusing in particular on four key areas of sectoral specialism where enhanced innovation capabilities benefited SMEs in the target region. As such, the project partners are of the view that the programme has contributed to several 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 years. The Enterprise 2025 vision was for Ireland to be the best place to succeed in business, delivering sustainable employment and higher standards of living for all. It recognised 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'[131]; and

[130] 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.
[131] Enterprise 2025. Department of Jobs, Enterprise and Innovation (Ireland), 2015.

- The innovation strategies of Northern Ireland and Scotland also acknowledged the importance of knowledge exchange between firms and other actors in the innovation ecosystem[132].

In addition, the project partners note that the OECD identified the need for interventions in border regions to ensure that cross-border innovation opportunities were available to SMEs – reflecting the reality that innovation and the transfer of knowledge do not stop at borders[133].

In summary, the Evaluation Team is of the view that the Co-Innovate project has contributed to a range of strategic imperatives that exist across the eligible region.

10.9 Barriers to Cross-Border Co-operation

The Project Partners note that the only barrier to cross-border co-operation that the priority axis is not addressing relates 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, and training consultancy costs. The Project Partnership notes that these costs are eligible for support under similar R&I interventions.

10.10 Potential Legacy Impacts

According to the project partners, the long-term benefits/durability of the outputs of the proposed project will include:

- 1,412 SMEs 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;
- 447 SMEs[134] have participated in detailed Innovation Audits which provide a framework for them to implement their visions beyond the life of this project;
- Support agencies engaged in Strands 1 and 2 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 66 SME partnerships develop with academic institutions will persist. This will encourage academic institutions to consider further partnerships with SMEs in other programmes.
- Linked to Strand 4, there are potential opportunities for the participating businesses to employ their project manager involved in their Strand 4 project.
- The number of enterprises exporting should increase, with consequent improvement in growth and employment performance across the eligible region.

Furthermore, the project partnership noted that the success of the partnership working and the ability to provide SMEs with the right type of support on their innovation journey will be a legacy of the project

[132] Department of Enterprise, Trade and Investment, Northern Ireland Innovation Strategy, 2014-2025, 2014; and Scottish Enterprise, Innovation Strategy 2015-2018, 2015.
[133] OECD, Regions and Innovation: Collaborating across-borders, 2013.
[134] Forecasted to be 469 SMEs by the end of the programme.

11. SUMMARY POSITION OF THE PROJECTS (AT THE TIME OF REPORT)

11.1 Project Expenditure to Date

Table 11.1 provides a summary of the total estimated expenditure to July 2022 and also the proportion of 'project time' that has passed as of July 2022.

Table 11.1: Project Costs – Anticipated and Estimated Actual July 2022

Project	Anticipated Total (€)	Total Actual/ Estimated Expenditure in July 2022[135]	Anticipated % of the total budget	Proportion of Timescale Passed in July 2022
Objective 1.1				
NWCAM	8,779,853	8,366,831	95%	100%
Renewable Engine	6,104,995	5,440,803	89%	100%
Bryden Centre	9,752,680	8,791,852	90%	100%
SPIRE 2	6,703,246	6,016,351	90%	97%
ECME	8,362,917	8,125,466	97%	99%
BREATH	8,905,366	8,131,646	91%	100%
CPM	9,424,927	8,155,296	87%	100%
Subtotal	**58,033,984**	**53,028,245**	**91%**	**-**
Objective 1.2				
Co-Innovate	20,707,185	14,655,403	71%	89%
Total	**78,741,169**	**67,683,648**	**86%**	**-**

Key points to note concerning expenditure (in July 2022) under INTERREG VA Programme Investment Priority 1: Research and Innovation include:

- At an overall Axis level, the eight projects have incurred expenditure of almost nine-tenths (86%) of their total budget. However, this differs considerably between the two Objectives:
  - The seven projects under Objective 1.1 have incurred 91% of their total budget; and
  - Whilst Objective 1.2 has incurred less than three-quarters (71%) of their total budget.
- Whilst five of the Objective 1.1 projects were complete as of July 2022, four[136] of the projects had only recently (in June 2022) completed at that time. A fifth project (Renewable Engine) which was completed in January 2022 advised the Evaluation Team that they were behind on the claims process. Therefore the expenditure presented may not reflect the final expenditure position for the Investment Priority due to the timing of submission and verification of final claims.
- All eight projects advised the Evaluation Team that they would have some level of underspend.

[135] Estimated total expenditure is used for those projects that are still in progress whereas for those projects that have been completed actual expenditure is used.
[136] NWCAM, BREATH, Bryden Centre and CPM.

11.2 The Extent to which the Priority Axis Output & Result Indicators have been achieved

11.2.1 Specific Objective 1.1

Encouragingly, despite the onset of the COVID-19 pandemic, at an overall Specific Objective 1.1 level, all of the output indicators have been achieved and in most cases, exceeded by some considerable margin[137].

Table 11.2: Overview of progress made towards the Output Indicators under Specific Objective 1.1

Output Indicator	Programme Target	Combined project targets (based on Letter of Offers)	Actual Output[138]								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	79	7	10	10	10	16	5	127	**185**	**825%**	**134%**
No. of enterprises receiving grants	10	26	3	5	4[139]	12	2	3	4	**33**	**230%**	**27%**
No. of enterprises receiving non-financial support	20	79	7	10	10	10	16	3	127	**183**	**815%**	**132%**
Years of PhD (or above) level research	514	635.69	93.6	60.58	104.86	103.09	81.8	86.7	117.43	**648.06**	**26%**	**2%**
No. of enterprises cooperating with research institutions	10	79	7	8	10	12	16	5	127	**185**	**1750%**	**134%**
No. of enterprises participating in cross-border, transnational or inter-regional research projects	10	76	3	10	10	12	16	5	127	**183**	**1730%**	**141%**
No. of research institutions participating in cross-border, transnational or inter-regional research projects	5	29	3	4	4	5	4	4	5	**29**[140]	**480%**	-

[137] NB: At the time of writing, the SEUPB was in the process of commissioning a report to verify the outputs per project.
[138] Source: Project Progress Reports and discussion with Project Partnerships.
[139] Discussion with project, and the project's presentation to SEUPB in March 2022, albeit the most recent progress report states 0.
[140] This includes 14 unique research institutions, as follows UU (involved in 5 projects), QUB (4), DkIT (3), LyIT (3), UHI (3), IT Sligo (2), UoS (2), AFBI (1), SWC (1), NUIG (1), DCU (1), UCD (1), UoG (1) and UWS (1).

As reflected in Section 1.3.4, Specific Objective 1.1's Result Indicator and Target was to achieve 75 peer-reviewed journal and conference publications with cross-border authorship and with the potential to create economic impact in two target sectors (HLS and Renewable Energy) on a three-year rolling average basis across the years 2021, 2022 and 2023. At the time of the Evaluation Team's analysis (May/June 2022) it is not possible to determine whether this target will be met. Albeit it is noted that SEUPB has advised that in its view, the cumulative number (201, per Table 11.3) of cross-border publications reported by the seven projects over a 5 and a half year period (January 2017-May/June 2022) as having been generated (and notwithstanding that some of those publications may not ultimately contribute to the programme result indicator as a consequence that they may not have cross-border authorship and/or have the potential to create economic impact) suggest that the final target of 75 for the end of 2023 (or 225 across 2021, 2022 and 2023) *"is achievable, if far from certain"*. The Evaluation Team would concur with the *"far from certain"* sentiment suggested by SEUPB and recommend that SEUPB introduce robust monitoring for the final phases of the Programme to definitively ascertain the extent to which the project target was achieved.

The Evaluation Team notes that its consultations with the seven Specific Objective 1.1 projects during April/May 2022 indicated that they had achieved 201 peer-reviewed publications with cross-border authorship at that time (see Table 11.3)[141], which is 36% lower than the combined projects' targets (i.e. the targets featured in the projects' Letters of Offer).

Table 11.3: Specific Objective 1.1 - Overview of progress made towards the Letter of Offer targets relating to the number of peer-reviewed publications with cross-border authorship

Project	Targets (per Letters of Offer)	Actual (as of April/May 2022)[142]	% Achieved	Notes
BREATH	33	50	152%	The project was due to be completed in June 2022.
NWCAM	30	18	60%	The project was due to be completed in June 2022. The project partnership advised the Evaluation Team that the two ROI academic partners were only involved in 3 (of 16) research projects, which limited the opportunities for cross-border publications.
ECME	81	49	60%	The project was due to be completed in July 2022. The project partnership highlighted that they might not achieve their target.
CPM	13	16	123%	The project was due to be completed in June 2022.
Renewable Engine	10	9	90%	The project was completed as of January 2022. The project advised (in May 2022) that an additional 3 publications with cross-border authorship had been submitted and were under review.
SPIRE2	78	39	50%	The project was due to be completed in September 2022. The project partnership noted that there was an inherent issue with the target requiring cross-border authorship, as the SPIRE 2 project 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 a demand on the quality and impact of the research publication as well as critical research protocols. Whilst the project lead highlighted that there were plenty of cross-border workings, it is not reflected in the paper numbers. The project lead indicated that the project is therefore unlikely to achieve the target of 78 publications with cross-border authorship.
Bryden Centre	68	20	29%	The project was due to be completed in June 2022. Concerning the cross-border focus of the target, the project partnership highlighted that it was unlikely that the project would achieve the target.
Total	**313**	**201**	**64%**	

[141] Source: It is noted that the actual number of peer-reviewed publications with cross-border authorship produced by the projects will be subject to independent verification (commissioned by SEUPB).
[142] Source: Consultations with project leads.

As reflected in Table 11.3, in April/May 2022, two of the seven Specific Objective 1.1 projects had achieved their Letter of Offer targets relating to the number of peer-reviewed publications with cross-border authorship. However, of the five that had not, four did not consider that they would achieve the targets set in their LoO or indeed that there was scope for many more such publications to be derived from their projects (notwithstanding any lag that might be experienced between the time that research activity is undertaken, and research papers being developed and published). For that reason, the Evaluation Team considers that it is unlikely that the Programme Target will be achieved.

In addition, two Specific Objective 1.1 projects had targets relating to publications other than those with cross-border authorship. Of the two projects, at the time of consultation, BREATH was unable to provide an exact figure against its target of 15 Peer-Reviewed Publications with Inter-Regional Authorship but was confident that the target had been exceeded.

Table 11.4: Specific Objective 1.1 - Overview of progress made towards the Letter of Offer targets relating to the number of 'other' publications

Project	Letter of Offer Target	Actual Achievement
BREATH	15 Peer-Reviewed Publications with Inter-Regional Authorship	Exceeded
CPM	30 'Other' Publications	56 - Exceeded

11.2.2 Specific Objective 1.2

As of April 2022, the Co-Innovate project had achieved the majority of its output indicator targets but was slightly under the targeted number of enterprises receiving one-to-one innovation advice (linked to Strand 2) and engaging an innovation intern, on a cross-border basis (linked to Strand 4). Albeit it is noted that the Co-Innovate Partners advised that they were confident that the target number (N=469) of enterprises receiving one-to-one innovation advice would be met by the end of the Programme.

However, the Co-Innovate project partners advise that due to the timing required to recruit an intern for a project to be implemented, it is unlikely that the number of enterprises engaging an innovation intern on a cross-border basis target, will increase beyond the 66 featured in Table 11.5 (representing a small shortfall of four such projects).

Table 11.5: Overview of progress made (at April 2022) towards the Output Indicators under Specific Objective 1.2

Output Indicator	Target	Actual	Variance
No. of enterprises receiving support	1,408	1,412	+<1%
No. of enterprises receiving non-financial support	1,408	1,412	+<1%
No. of enterprises receiving one-to-one innovation advice	469	447	-5%
No. of enterprises in receipt of an innovation capability development programme	94	97	+3%
No. of enterprises engaging an innovation intern on a cross-border basis	70	66	-6%
No. of enterprises cooperating with research institutions	50	66	+32%
No. of enterprises participating in cross-border, transnational or interregional research projects	30	35	+17%
No. of enterprises receiving grants	30	35	+17%
No. of research institutions participating in cross-border, transnational or interregional research projects	5	5[143]	0%

[143] The five research institutions are participating in eight Strand 5 research projects: South West College (1), Scottish Association for Marine Science (1), Dundalk Institute of Technology (2), Ulster University (2) and Queen's University Belfast (2).

As reflected in Section 1.3.4, Specific Objective 1.2's Result Indicator and Target was to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023.[144]

The Evaluation Team notes that the number of SMEs in the eligible region greatly exceeds the number of businesses (1,408) that were anticipated to participate in the Co-Innovate Programme. As such, it would not have been possible for the Co-Innovate Programme to achieve the 11% uplift (featured in the target) in isolation. This was discussed with SEUPB and NISRA who advised that the approach adopted in setting specific Objective 1.2's Result Indicator was in line with guidance issued by the EU during March 2014 concerning monitoring and evaluation during the programme period 2014-2020.[145] The guidance document outlines the following advice:

- The intended *result* is the specific dimension of well-being and progress for people that motivates policy action, i.e. what is intended to be changed, with the contribution of the interventions designed.
- Once a result has been chosen it must be represented by appropriate measures. This can be done by identifying one or more result indicators. *Result indicators* are variables that provide information on some specific aspects of results that lend themselves to be measured.
- Different factors can drive the intended result towards or away from the desired change.
- *Outputs* are the direct products of programmes; they are intended to contribute to results;
- The values of result indicators, both for baselines and at later points in time, in some cases, can be obtained from national or regional statistics. In other cases, it might be necessary to carry out surveys or to use administrative data, such as a registry of enterprises or unemployment benefit recipient data.
- Concerning evaluation, the guidance notes that changes in the result indicator are due to the actions co-financed by the public intervention, for example by the Funds, as well as *other factors*. In other words, the difference between the situation before and after the public intervention does *not* equal the effect of public intervention:

  Change in result indicator = contribution of intervention + contribution of other factors

As such, SEUPB and NISRA advised that the result indicator for Specific Objective 1.2 was not anticipated to measure the direct impacts of the projects supported and instead it was anticipated to measure changes in the characteristics of a given area due to programme interventions and/or other factors (i.e. external to the Interreg VA programme).

The Evaluation Team notes that c.100 SMEs engaged in research and innovation involving cross-border collaborations as a result of the Co-Innovate Programme. They were:

- The 66 enterprises that engage an innovation intern on a cross-border basis; and
- The 35 enterprises that participated in cross-border, transnational or interregional research projects.

Therefore, it is likely that the Co-Innovate Programme has made a modest contribution to the Result Indicator and Target to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023.

[144] 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.

[145] Programming Period 2014-2020, Guidance Document on Monitoring and Evaluation of European Cohesion Policy, European Regional Development Fund (March 2014)

11.2.3 Summary

Table 11.6 provides a summary of the progress made towards Priority Axis 1: Research and Innovation's overarching Output Indicators.

Table 11.6: Overarching progress towards the Priority's Output Indicators			
Output Indicator	**Target**	**Actual**	**Variance**
No. of enterprises receiving support	1,428	1,597	12%
No. of enterprises receiving grants	40	68	70%
No. of enterprises receiving non-financial support	1,428	1,595	12%
Years of PhD (or above) level research	514	648	26%
No. of enterprises cooperating with research institutions	60	251	318%
No. of enterprises participating in cross-border, transnational or interregional research projects	40	218	445%
No. of research institutions participating in cross-border, transnational or interregional research projects	10	34[146]	240%
No. of enterprises receiving one-to-one innovation advice	469	447	-5%
No. of enterprises in receipt of an innovation capability development programme	94	97	3%
No. of enterprises engaging an innovation intern, on a cross-border basis	70	66	-6%

[146] This includes 15 unique research institutions, as follows UU (involved in 6 projects), QUB (5), DkIT (4), LyIT (3), UHI (3), SWC (2), IT Sligo (2), UoS (2), AFBI (1), NUIG (1), DCU (1), UCD (1), UoG (1), UWS (1) and Scottish Association for Marine Science (1).

12. CONCLUSIONS AND RECOMMENDATIONS

12.1 Introduction

This report has considered the effectiveness and impact of the investment made under the INTERREG VA Programme Investment Priority Axis 1 – Research and Innovation. This section of the report considers key conclusions and recommendations arising from the review of each of the eight projects supported.

It should be noted that this report represents the final in the series of three impact evaluation reports. As a consequence of the outworkings of the Covid-19 pandemic and resultant delays caused in the implementation of projects, two of the eight individual projects supported under Priority Axis 1 had yet to be fully completed at the time of this report. However, for SEUPB's reporting requirements to the EU Commission, it was necessary to develop the final evaluation report at this time.

12.2 Conclusions

12.2.1 Overarching Conclusion on Activity Supported

Launched in January 2016, the INTERREG VA Programme was one of over sixty funding programmes across the EU that had 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, aimed to promote greater levels of economic, social and territorial cohesion to create a more prosperous and sustainable cross-border region.

The INTERREG VA Programme had four key priority axes, which were selected to address identified weaknesses in the programme region's economy, as set out in the Co-operation Programme for the INTERREG VA Programme 2014-2020. One of those was Priority Axis 1: Research and Innovation. The Co-operation Programme identified that the key aim of Priority Axis 1: Research and Innovation was 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 was anticipated that this priority axis would 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).

The Priority Axis had two specific objectives:

- Firstly, to increase business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences (HLS) and Renewable Energy (Specific Objective 1.1); and
- Secondly, 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).

Ultimately, seven projects were funded under Specific Objective 1.1 of the R&I Priority Axis with a total anticipated project cost of c. €58m and one project - the Co-Innovate Programme – was funded under Specific Objective 1.2, and had a total anticipated cost of c. €20.7m.

At an overall level, the Evaluation Team's review of each of the seven projects supported under Specific Objective 1.1 indicates that they have:

- Placed considerable investment in two key areas (i.e. Health & Life Sciences and Renewable Energy) that have wide-reaching strategic and social importance and offer considerable potential for the further development of high value-added products and processes, alongside key contributions to facilitating healthier populations and a greener environment. Consequently, the work of the projects has contributed to the shared policy agenda of the eligible region 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;
- Each of the project partnerships was comprised of academic institutions (and individual academics) and organisations of considerable standing and expertise in their area of focus. However, for many, it was their first time engaging either at all or to the extent made possible with the INTERREG VA funding on a cross-border cross-jurisdictional basis. On that basis, it is clear that the projects have successfully encouraged the creation of new, and supported the development of existing, cross-border R&D&I partnerships (including stakeholders from academic institutions, SMEs and Government agencies).
- As reflected through the Evaluation Team's consultations with members of individual project partnerships, the seven projects enabled the sharing of expertise and experience to an extent that the project partners consider would simply not have been possible without INTERREG VA funding, and thereby have contributed considerably to knowledge transfer and an overall increase in the level of research and innovation competence and activity across the programme area in a strategic way that is designed to contribute toward the development of a more competitive, high value-added economy.
- Importantly, for the economy of the eligible region, a key outworking of the seven projects has been a considerable increase in the number of PhD-level researchers who offer the potential to either continue to research in two key sectoral areas or to become employed in those industry sectors.

Furthermore, the Evaluation Team's review of the Co-innovate project which was the only project supported under Specific Objective 1.2, indicates that it has:

- Supported over 1,400 SMEs to overcome a range of barriers and to take the initial steps to enhance the level of innovation that they were engaged in, increase their 'innovation capacity' and for many to engage with a research institution for the first time and/or to engage collaboratively on a cross-border basis for the first time;
- Indeed, many of those businesses successfully progressed through the programme's support framework and successfully introduced new innovative products and processes, which should serve to help build a strong export-based economy in the eligible region.

On an overall basis, the Evaluation Team considers that it is evident that the projects supported under Priority Axis 1: Research and Innovation have contributed to its aim 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".* They have also successfully helped 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).

12.2.2 The extent to which the Project Outputs have been achieved

As reflected in Section 2.3, despite the onset of the COVID-19 pandemic, at an overall level, each of the output indicators that were established for Specific Objective 1.1 has been achieved and in most cases, exceeded by some considerable margin.

At an individual Specific Objective 1.1 project level, at the time that the Evaluation Team consulted with the projects (i.e. April/May 2022), five projects[147] had achieved each of their output indicators, whilst the remaining two projects (the Bryden Centre and SPIRE 2) had achieved the majority of their output indicators. For those two projects, the project partnerships were confident that the remaining outputs would be achieved before the projects were completed (June and September 2022 respectively) except for the Bryden Centre's targets concerning the number of enterprises receiving grants (four versus a target of eight). The project noted that as a consequence of the pandemic-related lockdowns, businesses had been reluctant to engage with the Knowledge Exchange placements aspects of the project's activity, as it would have required having PhD students on-site at a time when their business operations were in flux.

Under Objective 1.2, the Co-Innovate project had achieved (and in many instances exceeded) seven (of 9) of the project output indicators at the time of consultation (April 2022). Of the two remaining targets, the Co-Innovate Partners are confident that the target number (N=469) of enterprises receiving one-to-one innovation advice (Strand 2) will be met by the end of the Programme (i.e. March 2023), however, they anticipate, as a consequence of the pandemic-related restrictions, that there will continue to be a small shortfall (of 4 projects) in the number of enterprises engaging an innovation intern on a cross-border basis target (linked to Strand 4).

12.2.3 The extent to which the Specific Objectives & Result Indicators have been achieved

Specific Objective 1.1's Result Indicator and Target was to achieve 75 peer-reviewed journal and conference publications with cross-border authorship and with the potential to create economic impact in two target sectors (HLS and Renewable Energy) on a three-year rolling average basis across the years 2021, 2022 and 2023. At the time of the Evaluation Team's analysis (May/June 2022) it is not possible to determine whether this target will be met. Albeit it is noted that SEUPB has advised that in its view, the cumulative number (201, per Table 11.3) of cross-border publications reported by the seven projects over a 5 and a half year period (January 2017-May/June 2022) as having been generated (and notwithstanding that some of those publications may not ultimately contribute to the programme result indicator as a consequence that they may not have cross-border authorship and/or have the potential to create economic impact) the suggest that the final target of 75 for the end of 2023 (or 225 across 2021, 2022 and 2023) *"is achievable, if far from certain".*

The Evaluation Team would concur with the *"far from certain"* sentiment suggested by SEUPB and recommend that SEUPB introduce robust monitoring for the final phases of the Programme to definitively ascertain the extent to which the project target was achieved.

[147] NWCAM, Renewable Engine, ECME, BREATH and CPM.

The Evaluation Team notes that its consultations with the seven Specific Objective 1.1 projects during April/May 2022 indicated that they had achieved 201 peer-reviewed publications with cross-border authorship at that time (see Table 12.1). which is 36% lower than the combined projects' targets (i.e. the targets featured in the projects' Letters of Offer).[148]

Table 12.1: Specific Objective 1.1 - Overview of progress made towards the Letter of Offer targets relating to the number of peer-reviewed publications with cross-border authorship			
Project	**Targets (per Letters of Offer)**	**Actual (as of April/May 2022)[149]**	**% Achieved**
BREATH	33	50	152%
NWCAM	30	18	60%
ECME	81	49	60%
CPM	13	16	123%
Renewable Engine	10	9	90%
SPIRE2	78	39	50%
Bryden Centre	68	20	29%
Total	**313**	**201**	**64%**

In April/May 2022, two of the seven Specific Objective 1.1 projects had achieved their Letter of Offer targets relating to the number of peer-reviewed publications with cross-border authorship. However, of the five that had not, four did not consider that they would achieve the targets set in their LoO or indeed that there was scope for many more such publications to be derived from their projects (notwithstanding any lag that might be experienced between the time that research activity is undertaken, and research papers being developed and published). For that reason, the Evaluation Team considers that it is unlikely that the Programme Target will be achieved.

In addition, two Specific Objective 1.1 projects had targets relating to publications other than those with cross-border authorship. Of the two projects, at the time of consultation, BREATH was unable to provide an exact figure against its target of 15 Peer-Reviewed Publications with Inter-Regional Authorship but was confident that the target had been exceeded.

Table 11.4: Specific Objective 1.1 - Overview of progress made towards the Letter of Offer targets relating to the number of 'other' publications		
Project	**Letter of Offer Target**	**Actual Achievement**
BREATH	15 Peer-Reviewed Publications with Inter-Regional Authorship	Exceeded
CPM	30 'Other' Publications	56 - Exceeded

It is noted that private sector industry was intrinsically involved in each of the seven projects supported under Specific Objective 1.1. As such, the Evaluation Team considers that the projects supported have successfully contributed to increasing business and industry-relevant research and innovation capacity across the region within two target sectors; Health and Life Sciences (HLS) and Renewable Energy.

Specific Objective 1.2's Result Indicator and Target was to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023. The Evaluation Team notes that the number of SMEs in the eligible region greatly exceeds the number of businesses (1,408) that were anticipated to participate in the Co-Innovate Programme. As such, it would not have been possible for the Co-Innovate Programme to achieve the 11% uplift (featured in the target) in isolation. This was discussed with SEUPB and NISRA who advised that the approach adopted in setting specific Objective 1.2's Result Indicator was in line with guidance issued by the EU during March 2014 concerning monitoring and evaluation during the programme period 2014-2020, whereby the result indicator was not anticipated to measure the direct impacts of the projects supported. Instead, it was anticipated to measure changes in the characteristics of a given area due to programme interventions and/or other factors (i.e. external to the Interreg VA programme).

[148] Source: It is noted that the actual number of peer-reviewed publications with cross-border authorship produced by the projects will be subject to independent verification (commissioned by SEUPB).
[149] Source: Consultations with project leads.

The Evaluation Team notes that c.100 SMEs engaged in research and innovation involving cross-border collaborations as a result of the Co-Innovate Programme. They were:

- The 66 enterprises that engage an innovation intern on a cross-border basis; and
- The 35 enterprises that participated in cross-border, transnational or interregional research projects.

Therefore, it is likely that the Co-Innovate Programme has made a modest contribution to the Result Indicator and Target to increase the percentage of SMEs in the eligible region involved in research and innovation involving cross-border collaborations from a baseline position of 22% in 2014 to 33% by 2023.

In total, the Co-Innovate Programme supported over 1,400 businesses in the eligible region. On that basis, the Evaluation Team considers that the project successfully achieved Specific Objective 1.2 i.e. it served 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.

12.2.4 Factors that have impacted project delivery including the achievement of Project Output and Result indicators and the Priority's Specific Objectives

Each of the seven projects that received support under Specific Objective 1.1 advised that they encountered issues that impacted the delivery of their respective projects, most notably associated with the outworkings of the pandemic and its associated lockdowns. Examples of issues commonly cited by the projects' partners include:

- **Covid-19 –** The Covid-19 pandemic impacted all projects, for example, the Covid-19 pandemic and the related restrictions on the movement of people meant that:
  - Various staff across the project partnership and/or the private sector businesses that they were working with started working remotely and/or had furloughed staff.
  - The projects lost access to laboratories across each of the academic partners, to testing and development sites (within the industry partners) and to patients, which had a substantial impact on project progress.
- **Brexit** - A further marketplace factor of considerable significance that occurred during the project period was the withdrawal of the United Kingdom (UK) from the European Union on 31 January 2020. Several of the projects' partners noted during consultation that the outworkings of Brexit resulted in the project facing difficulties, for example in securing materials;
- **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 projects. A commonly shared view amongst the Partners was 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 arisen because several 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 Health and Life Sciences). This inadvertently created significant demand within the market for those students at the one time, resulting in a shortage of available students and, by association, delays in recruitment.

  On the supply side, it was noted by several partners that there had been limited appetite from domestic applicants which was suggested might have resulted from several factors including the scale of the research bursary that was available to potential students, 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 demand and supply side factors, several partners indicated that they had to ultimately seek applications from potential international PhD students.

- **Staff mobility issues** – Related to the above, difficulties had been encountered concerning non-EU resident PhD students taking up research positions in the eligible region due to visa-related restrictions. At the time of the first report, several the Projects' Partners expressed concern that such mobility issues might potentially be exacerbated following the UK's departure from the EU (i.e. following 'Brexit');

- **'Background' and 'foreground' IP issues impacting business recruitment and wider engagement in research projects** - Several of the projects' partners noted that they had faced difficulties encouraging business engagement on their respective projects due to concerns relating to IP. For some businesses, these concerns were 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 anticipated to be owned by the academic institutions;

- **EU/SEUPB and University procurement requirements hindering the progression of research** - Several the project partners considered that their project's progression 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)** - Some project partners indicated that there have been several changes to the profile of their project's research team during the initial delivery period which had, on occasions slowed project progress;

- **Changes to industrial partners** - A small number of project partners indicated that their originally anticipated industry partners had to be replaced due to a variety of business-specific circumstances (e.g. businesses going into administration, businesses having more pressing priorities); and

- **The claims process adversely impacted business engagement** - A small number of project partners noted that the administration and bureaucracy associated with the claims process had resulted in businesses leaving their project and other businesses not being willing to receive the financial support that was potentially available through the projects.

Encouraging, however, whilst the issues encountered no doubt caused operational complications for projects and combined to slow progress towards elements of the output indicators (e.g. number of PhD years delivered), each of the projects advised that, in general, none of the issues encountered ultimately had an overlay adverse impact on the longer-term achievement of the Project Output Indicators. Concerning this, the projects spoke positively about the role that SEUPB's staff played and the flexibility shown in allowing budgets to be amended and/or project timescales to be extended to account for the issues faced.

In terms of the Co-Innovate Programme (supported under Specific Objective 1.2), the project partners similarly advised that they encountered many similar issues to those noted above, such as the impact of the pandemic-related restrictions on travel that hindered efforts to encourage cross-border collaboration; the uncertainty caused by Brexit amongst businesses that had influenced businesses' perceptions of risk and willingness to invest in innovation activities. Similarly, though, the Co-Innovate Partners engaged closely with SEUPB to agree on new project timelines and subsequently achieved all almost of their anticipated outputs.

12.2.5 Key areas of best practice and learning

Encouragingly, the projects partners in receipt of support under Specific Objective 1.1, cited several 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 the 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 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);
- The utilisation of industry facilities (e.g. NIACE) to support project delivery (NWCAM);
- PhD students being allocated a supervisor in another area within the eligible region to support project progress and their development (BREATH, Bryden Centre, Renewable Engine);
- 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 as resilience, entrepreneurship, presentation and time management skills (ECME, NWCAM, SPIRE 2);
- 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 concerning INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allows for a 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 complementary 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.

Concerning the Co-Innovate Programme (supported under Specific Objective 1.2), the project partners note that whilst, in hindsight they consider that the Programme's structure and content may be too complex for some SMEs (particularly at Strand 2), they are of the view that the multifaceted 'umbrella' of support delivered through the Co-Innovate Programme was unique and was ultimately successful in increasing SMEs' knowledge and understanding of innovation, enhancing their capacity to engage in collaborative projects and ultimately de-risking their initial steps into undertaking a cross-border/transnational collaborative by contributing towards its financial costs.

Linked to this, it is considered that the Co-Innovate Programme's use of a 'funnel' model approach and use of both group workshops and bespoke one-to-one support served to 'handhold' businesses with limited 'innovation experience' through an unfamiliar environment and helped them to reduce the level of risk associated with the introduction of new products and processes.

12.2.6 New ways of working/partnerships/relationships created

Across the eight projects, a myriad of new cross-border and cross-jurisdictional relationships have been developed and which are reflected, in part, in the earlier sections of this report. Most positively, each of the project partners has indicated that they hope to continue to work in partnership and share knowledge and good practice with both their project partners and stakeholders engaged with.

12.2.7 Synergies between projects

Our discussions with the Projects Partners indicate that several synergies have emerged between the individual projects funded under Specific Objective 1.1, for example:

- NWCAM and SPIRE 2 collaborated to offer multi-disciplinary working/training sessions (on commercialisation and career development for example) to their PhD students to offer a cross-over of INTERREG VA thematic areas and open the PhD researchers to new insights into new research disciplines that they would not have otherwise had exposure to.
- Several PhD students from the Renewable Engine project attended the Bryden Centre Summer School 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;
- SPIRE 2, ECME and CPM management teams at Ulster work closely with staff across common Doctoral College activities including generic training and development of PhDs and delivering on the Marie Curie principles for research;
- Given the synergies between the NWCAM, CPM and ECME projects the Project Managers coordinated project events to avoid duplication in the marketplace;
- Several the projects engaged in the informal 'Project Managers' Group' which facilitated open discussion concerning INTERREG and how to approach particular SEUPB requirements. According to the project partners, this allowed for a cross-over of learning and insights that have been gained by each project manager.

Several project partners also suggested that support delivered through their respective projects 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).

12.2.8 Impact on Business and Industry

It is the view of the Evaluation Team that the full impact of the projects, funded under Specific Objective 1, on business and industry will only become fully measurable in the medium-to-longer term given 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 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, the technology's starting point on the TRL scale and the associated degree of novelty.

Notwithstanding this, the project partners noted several positive activities, outputs and outcomes 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, and the development of new and/or adapted products and processes. For example:

- **Knowledge Transfer/Exchange** - The projects provided access to expertise and provided opportunities for learning and knowledge transfer between the academic institutions and industrial partners. For example, on CPM the Voscuris team were able to use the registry questionnaire as a use case for gaining user feedback and further development of mobile data collection tools, with the potential to replace the RedCap solution if suitable. The insight gained from this collaboration informed the later development of the Voscuris Covid Note app, a tool for enabling patients experiencing post-covid syndrome to record their symptoms.
- **Development of industrial competencies** - For example, on the NWCAM project 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 healthcare products** – For example:

  – On NWCAM, Armstrong Medical launched its AquaVENT® VT breathing circuit just before the WHO declared the global coronavirus pandemic. AquaVENT® VT benefits from R&D generated through the NWCAM collaboration with UU which developed a novel method of production of tubing used to create a 'breathable' expiratory limb. The research enabled Armstrong Medical to significantly reduce the risks associated with the pooling of condensed water vapour in the tubing. The innovative step also minimised the interference by moisture on sensitive electronics on ventilators, relieving hospital caregivers of some aspects of the continuous monitoring of the equipment in use.

  This technology has now been incorporated into several critical care ventilator circuits for adult, paediatric and neonatal patients who require assistance with their breathing. By expanding the range of breathing circuits and electromedical devices Armstrong Medical supplies to hospital intensive care units, they were able to respond rapidly to global demand for these critical respiratory devices as caregivers around the globe scrambled to secure the means by which to treat COVID-19 patients.

  – ProAxsis Ltd used its ECME funding to develop an assay for the detection of the biomarker Cathepsin in COVID-19 patients.

- **Development of new products –** For example, the Renewable Engine project's development grants supported five businesses to produce 5 new product prototypes, and one of the SPIRE 2 funded partners, Arbarr, in conjunction with DKIT, developed new products concerning providing battery and heat storage to an off-grid island.
- **Development of new processing models** – For example, on NWCAM, IT Sligo used AI to develop a predictive production model to save energy for GSK. GSK introduced the model in its Irvine plant and it resulted in a reduction in energy costs of 5-10%. GSK plan to roll the model out into all its UK plants, with the potential to roll out across Europe.
- **Identification of new clinical targets –** For example, the BREATH project identified a potential new clinical target as a result of the collaboration with Almac Discovery.
- **Supported industry to secure additional investment –** For example, the Bryden Centre project supported industry to secure follow-on funding of c.£1.8m (as of April 2022), and the ECME project supported 42 Genetics Ltd to secure further research funding totalling £700k from Innovate UK.

12.2.9 Contribution of the Priority Axis to Policy Objectives

The Evaluation Team is of the view that the eight projects funded under the Priority Axis 1: Research & Innovation have successfully contributed to a wide variety of policy objectives and in particular those relating to the EU Cohesion Policy and EU 2020 objectives. Cohesion Policy is the EU's main investment policy which targets all regions and cities in the European Union to support job creation, business competitiveness, economic growth, sustainable development, and improve citizens' quality of life.

In line with the Cohesion Policy's thematic objectives, across the eight projects, the activities supported have served to:

1. Strengthen research, technological development and innovation;
2. Enhance the competitiveness of SMEs
3. Support the shift towards a low-carbon economy;
4. Promote climate change adaption, risk prevention and management;
5. Preserve and protect the environment and promote resource efficiency;
6. Promote sustainable and quality employment and support labour mobility;
7. Invest in education, training and lifelong learning.

In addition, in line with EU2020 Objectives, the projects supported have contributed to the following priorities:

- **Smart growth**: developing an economy based on knowledge and innovation.
- **Sustainable growth**: promoting a more resource-efficient, greener and more competitive economy.

12.2.10 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. Health and Life 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.

12.3 Recommendations

To help inform similar programmes of activity going forward, the Evaluation Team makes the following recommendations;

1. Given the importance of Specific Objective 1.1's Result Indicator and Target to the overall Investment Priority Axis 1 – Research and Innovation, it will be of crucial importance that SEUPB introduces robust monitoring for the final phases of the Programme to definitively ascertain the extent to which the project target was achieved.

2. By way of aiding post-project evaluation and potentially supporting the programme's ability to measure 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.

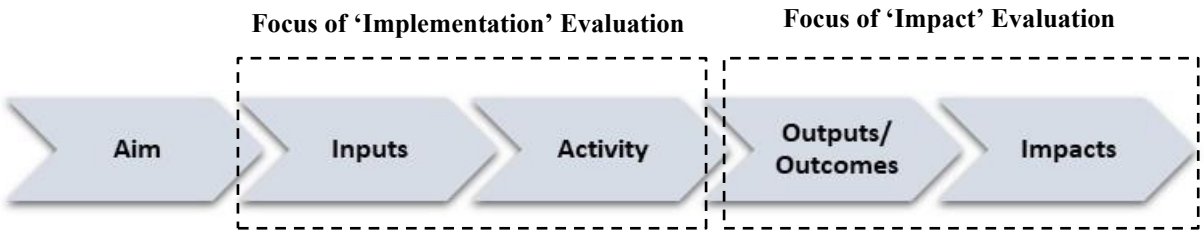
3. Linked to recommendation 1, before a project receives a Letter of Offer SEUPB should ensure that robust challenge is given to the assessment of an individual project's potential contribution to overarching targets indicators.

4. By way of aiding ongoing Evaluation, the Project Partners should be encouraged to review their progress reporting and project-level post-project evaluation templates 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.

5. The 'logic chain' to Evaluation illustrates the intrinsic linkages between an intervention's aims, inputs, activities, outputs and outcomes (as depicted below). However, the Evaluation Team understands that SEUPB has commissioned two separate evaluations – an 'Implementation' Evaluation and an 'Impact' Evaluation - which focus on assessing the progress made by the Priority (and projects supported therein) at different stages of the logic chain.

Figure 12.1: 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.

6. Most projects considered that aspects of the INTERREG VA programme were administration intensive and on occasion, the level of work needed was not commensurate with the value offered to the project. Concerning such aspects of the programme, the following is recommended:

- Where possible, simplify both the procurement and claims processes used and ensure that the same processes are not overly prohibitive for SMEs and inadvertently act as a deterrent to their participation;
- If this is not possible, offer the projects and programme participations greater level of support to navigate and understand the processes used (including the use of eMS);
- Seek to streamline SEUPB's claims and verification processes so that projects are not placed under undue cashflow pressures;
- Simplify the project monitoring requirements and ensure that monitoring is focused on key indicators.

Appendix I – Overview of Key Strategies

EU Cohesion Policy 2014-2020

Cohesion Policy is the EU's main investment policy which targets all regions and cities in the European Union to support job creation, business competitiveness, economic growth, sustainable development, and improve citizens' quality of life.

The investments help to deliver many other EU policy objectives. It complements EU policies such as those dealing with education, employment, energy, the environment, the single market, research and innovation. In particular Cohesion Policy provides the necessary investment framework and strategy to meet the goals of the Europe 2020 Strategy for smart, sustainable and inclusive growth in the European Union.

Cohesion Policy set 11 thematic objectives supporting growth for the period 20142020 as follows:

8. Strengthen research, technological development and innovation;
9. Enhancing access to, and use and quality of, information and communication technologies;
10. Enhancing the competitiveness of SMEs
11. Supporting the shift towards a low-carbon economy;
12. Promoting climate change adaption, risk prevention and management;
13. Preserving and protecting the environment and promoting resource efficiency;
14. Promoting sustainable transport and improving network infrastructures;
15. Promoting sustainable and quality employment and supporting labour mobility;
16. Promoting social inclusion, combating poverty and any discrimination;
17. Investing in education, training and lifelong learning; and
18. Improving the efficiency of public administration.

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; research and innovation; climate change and energy; education; and 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 fewer 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 covers the coasts, and 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 on 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 co-operation 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
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 co-operation 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 Principles

The three Horizontal Principles 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 II – BREATH Project Publications

NB: The publications that include cross-border authorship are in bold.

Published Scientific Papers

1. Christopher P Pratt, Dika Kuljis, Gregg E Homanics, Jianjun He, Srikanth Dudem, Mark A Hollywood, Alison L Barth and Marcel P Bruchez (2017). Tagging of Endogenous BK Channels with a Fluorogen-Activating Peptide Reveals β4-Mediated Control of Channel Clustering in Cerebellum. Methods, Front. Cell. Neurosci.11:337. doi: 10.3389/fncel.2017.00337

2. 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.

3. Roe NA, Lundy FT, Litherland GJ, McGarvey LPA (2019). Therapeutic targets for the treatment of chronic cough. Curr Otorhinolaryngol Rep 7, 116–128 (2019). https://doi.org/10.1007/s40136-019-00239-9

4. Olga Zavaritskaya, Srikanth Dudem, Dongyu Ma, Rabab e Kaneez, Sarah Albrecht, Dmitry Tsvetkov, Mario Kassmann, Keith Thornbury, Mitko Mladenov, Claire Kammermeier, Gerard Sergeant, Nicholas Mullins, Ornella Wouappi, Hannah Wurm, Aimo Kannt, Maik Gollasch, Mark A Hollywood & Rudolf Schubert (2019). Vasodilation of rat skeletal muscle arteries by the novel BK channel opener GoSlo is mediated by the simultaneous activation of BK and Kv7 channels. British Journal of Pharmacology. 177 (5), 1164-1186.

5. **Srikanth Dudem, Roddy J Large, Shruti Kulkarni, Heather McClafferty, Irina G. Tikhonova, Gerard P Sergeant, Keith D Thornbury, Michael J Shipston, Brian A Perrino & Mark A Hollywood (2020). LINGO1 is a novel regulatory subunit of large conductance, Ca2+-activated potassium channels. Proc. Nat. Acad. Sci. USA117(4), 2194-2200. https://www.pnas.org/content/117/4/2194https://www.pnas.org/content/117/4/2194**

6. **Alexandria K. Driessen, Anna-Claire Devlin, Fionnuala T. Lundy, S. Lorraine Martin, Gerard P. Sergeant, Stuart B. Mazzone, Lorcan P. McGarvey. (2020) Perspectives on neuroinflammation contributing to chronic cough. European Respiratory Journal, 2000758; DOI: 10.1183/13993003.00758-2020. https://erj.ersjournals.com/content/56/4/2000758.article-info**

7. **Short B, Carson S, Devlin A-C, Reihill JA, Crilly A, MacKay W, Ramage G, Williams C, Lundy FT, McGarvey LP, Thornbury KD & Martin SL (2021) Non-typeable Haemophilus influenzae chronic colonization in chronic obstructive pulmonary disease (COPD) Critical Reviews in Microbiology. DOI: 10.1080/1040841X.2020.1863330**

8. Dudem S, Sergeant GP, Thornbury KD, Hollywood MA. (2021) Calcium-Activated K+ Channels (KCa) and Therapeutic Implications. Handb Exp Pharmacol. doi:10.1007/164_2021_459. PMID: 33945030.

9. **Carroll, E.L.; Bailo, M.; Reihill, J.A.; Crilly, A.; Lockhart, J.C.; Litherland, G.J.; Lundy, F.T.; McGarvey, L.P.; Hollywood, M.A.; Martin, S.L. Trypsin-Like Proteases and Their Role in Muco-Obstructive Lung Diseases. Int. J. Mol. Sci. 2021, 22, 5817. https://doi.org/10.3390/ijms22115817.**

10. **Kelly-Robinson, G.A.; Reihill, J.A.; Lundy, F.T.; McGarvey, L.P.; Lockhart, J.C.; Litherland, G.J.; Thornbury, K.D.; Martin, S.L. The Serpin Superfamily and Their Role in the Regulation and Dysfunction of Serine Protease Activity in COPD and Other Chronic Lung Diseases. Int. J. Mol. Sci. 2021, 22, 6351. https://doi.org/10.3390/ijms22126351**

11. Zhihui Fong, Caoimhin S Griffin, Roddy J Large, Mark A Hollywood, Keith D Thornbury, Gerard P Sergeant (2021). Regulation of P2X1 receptors by modulators of the cAMP effectors PKA and EPAC. Proc. Nat. Acad. Sci. USA (in press)

12. **Alkawadri T, Lorcan P McGarvey, Nicholas D Mullins, Mark A Hollywood, Keith D Thornbury and Gerard P Sergeant (2021). Contribution of postjunctional M2 muscarinic receptors to cholinergic nerve-mediated contractions of murine airway smooth muscle. Function, Volume 3, Issue 1, 2022, zqab053, https://doi.org/10.1093/function/zqab053**

13. Lim XR, Bradley E, Griffin CS, Hollywood MA, Sergeant GP, Thornbury KD. Fast voltage-dependent sodium (NaV) currents are functionally expressed in mouse corpus cavernosum smooth muscle cells. Br J Pharmacol. 2021 Nov 12. doi: 10.1111/bph.15728. Epub ahead of print. PMID: 34767251.

14. Short B, Delaney C, McKloud E, Brown JL, Kean R, Litherland GJ, Williams C, Martin, SL, MacKay WG and Ramage G. Investigating the Transcriptome of Candida albicans in a Dual-Species Staphylococcus aureus Biofilm Model. Frontiers in Cellular and Infection Microbiology. 2021;11:1142.

15. **Authors: Leanna M Morgan, S Lorraine Martin, Nicholas D Mullins, Mark A Hollywood, Keith D Thornbury1 and Gerard P Sergeant. Modulation of carbachol-induced Ca2+ oscillations in airway smooth muscle cells by PGE2. Cell Calcium. Accepted in final form Feb 2022.**

16. Douglas LEJ. Reihill JA, Ho MW-Y, Rendina AR, Wilcoxen KM, Martin SL. (2022) A highly selective, cell-permeable furin inhibitor BOS-318 rescues key features of cystic fibrosis airway disease. Cell Chemical Biology. Online ahead of print. DOI: https://doi.org/10.1016/j.chembiol.2022.02.001

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 Ca^{2+}- Activated K^{+} (BK) Channel Modulators. "Recent Advances in Synthesis and Chemical Biology XVI" symposium University College Dublin, Ireland. Published in Conference Book of Abstracts

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 Ca^{2+}- Activated K^{+} (BK) Channel Modulators. Technology & Innovation Centre (TIC), University of Strathclyde, Glasgow, UK Published in Conference Book of Abstracts

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 Ca^{2+}-Activated K^{+} (BK) Channel Modulators. RSC Organic Meeting – Ireland Division. Queen's University Belfast, Northern Ireland. Published in Conference Book of Abstracts

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 Ca^{2+} -activated K^{+} (BK) channel modulators. 22nd IUPAC International Conference on Organic Synthesis (22-ICOS). Published in Conference Book of Abstracts

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. Published in Conference Book of Abstracts

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 Published in Conference Book of Abstracts

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 Published in Conference Book of Abstracts

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. Published in Conference Book of Abstracts

10. **Nicholas D. Mullins, S Kulkarni, S Dudem, RJ Large, SL Martin, J Reihill, GP Sergeant, KD Thornbury and MA Hollywood (2019) Synthesis of novel peptides to investigate the inactivation of BK channels by the LINGO1 protein. Recent Advances in Synthesis and Chemical Biology XVIII Symposium, 06 December, Trinity College Dublin, Ireland. Published in Conference Book of Abstracts**

11. Nicholas D. Mullins, E. Bradley, R. Large, V. Bihun, G. Sergeant, M. Hollywood, K. Thornbury (2020) The effects of openers of large conductance Ca2+-activated K+ (BK) channels on agonist-induced phasic contractions in smooth muscle 6th RSC / SCI symposium on Ion Channels as Therapeutic Targets 24th-25th February, Wellcome Genome Campus Conference Centre, Cambridge, UK.

12. Flash Oral Presentation: Nicholas D. Mullins, E. Bradley, R. Large, V. Bihun, G. Sergeant, M. Hollywood, K. Thornbury (2020). The effects of openers of large conductance Ca2+-activated K+ (BK) channels on agonist-induced phasic contractions in smooth muscle 6th RSC / SCI symposium on Ion Channels as Therapeutic Targets 24th-25th February, Wellcome Genome Campus Conference Centre, Cambridge, UK.

Experimental Biology, 2018.

13. KD Thornbury, Victoria V Bihun, E Bradley, MA Hollywood & GP Sergeant. (2018). Effects of L-type Ca^{2+} blockers and the novel BK_{Ca} 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*

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14. 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*

15. **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***

16. **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***

17. **K Rabab, S Dudem, SL Martin, I. Tikhonova, KD Thornbury, GP Sergeant & MA Hollywood. Assessing the state dependent effects of SR-5-6 on K_v7.4 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***

18. **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***

19. **1T Alkawadri, KD Thornbury, MA Hollywood, L McGarvey, FT 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-***

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20. **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***

21. **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***

22. **M. Bailo, K. McCallu[1], L. Dunning, M. Stankovic, J. Reihill, L. Martin, G. Sergeant, C S. Goodyear, G. Litherland, J. Lockhart[1], 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***

23. 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*

24. **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***

25. **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***

26. 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*

27. 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*

28. **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***

29. 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*

Experimental Biology, 2019.

30. 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.

31. **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***

32. 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*

33. 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*

34. 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*

Physiology 2019

35. T Alkawadri, KD Thornbury, MA Hollywood, LP McGarvey, FT Lundy, GJ Litherland & GP Sergeant (2019) Involvement of M_2muscarinic 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*

Cough Conference: Reston Virginia, USA - June 2019

36. 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,* Reston Virginia*, USA. Lung. 2020 https://doi.org/10.1007/s00408-020-00328-3*

37. 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. A*merican Cough Conference,* Reston Virginia, *USA. Lung. 2020 https://doi.org/10.1007/s00408-020-00328-3*

38. N Downey, L McGarvey, SL Martin, A Crilly, FT Lundy (2019) Characterisation of exosomes isolated by ultracentrifugation from human primary bronchial epithelial cells. A*merican Cough Conference,* Reston Virginia*, USA. Lung. 2020 https://doi.org/10.1007/s00408-020-00328-3*

39. 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. A*merican Cough Conference,* Reston Virginia*, USA. Lung. 2020 https://doi.org/10.1007/s00408-020-00328-3*

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40. 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. https://kv7channels2019naples.org/fileadmin/user_upload/kv7channels2019naples/Kv7_2019_programme_finalWEB.pdf*

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42. 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. *Not published.*

43. 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. *Not published.*

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45. Kulkarni S, Dudem S, Large RJ, Sergeant GP, Thornbury KD and Hollywood MA (2019) LINGO proteins - novel inactivating regulatory subunits of BK channels. *Not published.*

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47. 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). *Not published.*

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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.74; Abstract S73, page 143. Translational science in COPD. https://thorax.bmj.com/content/74/Suppl_2/A49.1*

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60. Mariarca Bailo, L. Dunning, J. Brzeszczynska, K. Mcintosh, R. Plevin, S. L. Martin, G. P. Sergeant, C. S. Goodyear, G. S. Litherland, J. C. Lockhart, A. Crilly. Protease activated receptor 2 (PAR2) antagonism reduces pro-inflammatory cytokine production in bronchial epithelial cells. European Respiratory Journal 2020; 56: Suppl. 64, 2292. DOI: 10.1183/13993003.congress-2020.2292.https://erj.ersjournals.com/content/56/suppl_64/2292

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63. Kimberly Black, Andrew Mackenzie, Lynette Dunning, Anne Crilly, Joanna Brzeszczynska, Lorcan Mcgarvey, Keith Thornbury, Carl S. Goodyear, John C. Lockhart, Gary J. Litherland. Murine airway bronchodilation via Proteinase Activated Receptor 2. European Respiratory Journal 2020; 56: Suppl. 64, 1895. DOI: 10.1183/13993003.congress-2020.1895. https://erj.ersjournals.com/content/56/suppl_64/1895

64. Fawziye Tarhini, Lynette Dunning, Ann Crilly, Joanna Brzeszczynska, Lorcan Mcgarvey, Keith Thornbury, Carl S. Goodyear, John C. Lockhart, Gary J. Litherland. Repeated exposure to hydrogen peroxide enhances TGF-ß and LPS dependent inflammatory responses in BEAS-2B cells. European Respiratory Journal 2020; 56: Suppl. 64, 607. DOI: 10.1183/13993003.congress-2020.607. https://erj.ersjournals.com/content/56/suppl_64/607

London International Symposium on Cough (Virtual, 21st and 22nd January 2021)

65. A-C Devlin, OM Dunne, C Fulton, GP Sergeant, SL Martin, LP McGarvey, FT Lundy (2021) Modelling neuroinflammatory mechanisms in chronic cough using induced pluripotent stem cells (iPSCs). The 11th International Virtual Cough Symposium, London. Invited presentation *Not published*

66. OM Dunne, LP McGarvey, SL Martin, GP Sergeant, FT Lundy. (2021) ATP release from human bronchial epithelial cells and sensitisation of TRPV4 receptors in a human sensory neuronal model via P2X3 receptors. ***Not published***

67. NA Roe, FT Lundy, SL Martin, A Mousnier, G Litherland, L McGarvey. (2021) Elucidating the role of human rhinovirus in chronic cough associated with chronic obstructive pulmonary disease.*Not published*

British Thoracic Society Winter meeting (2020)

68. F Tarhini, A Crilly, J Brzeszczynska, L McGarvey, K Thornbury, CS Goodyear, JC Lockhart, GJ Litherland Oxidative stress driven inflammatory responses in lung epithelial cells. 2021. Thorax, 76 (Suppl. 1) DOI: 10.1136/thorax-2020-BTSabstracts.55

British Association for Lung Research - 24th June 2021

69. T Alkawadri, L McGarvey, MA Hollywood, KD Thornbury & GP Sergeant. Role of postjunctional M_2 muscarinic receptors in the enhancement of nerve-evoked contractions of murine airway smooth muscle.

British Thoracic Society Winter meeting (2021)

70. B. Short, C. Delaney, MC Butcher, G Litherland, C Williams, L Martin, K Thornbury, WG Mackay, G Ramage. Comparison of the lung microbiome in chronic obstructive pulmonary disease and in health: an in silico study. Thorax, 76 (Suppl. 2) DOI:10.1136/thorax-2021-BTSabstracts.

Appendix III – BREATH – Awards Received

In terms of the impact on students/academics, those involved in the BREATH project received the following awards:

- A QUB academic received a UKRI Innovation Scholar and was nominated for the QUB Postdoc Exceptional Support Award.
- A QUB PhD student received the following awards:

  - International Foundation of Ethical Research Graduate Fellowship;
  - Best abstract Cough Symposium, Jan 2021;
  - First prize at the Annual Postgraduate Forum QUB;
  - Won the postgraduate Hatton competition for her presentation describing the role of TRP channels and P2X receptors in dental pain. As the recipient of the Hatton postgraduate award, they received the honour of representing Ireland at the IADR general session and exhibition in Chengdu, China in June 2022.
  - 3rd place prize at the Wellcome-Wolfson Institute for Experimental Medicine 2nd year PhD symposium.
  - In conjunction with another QUB student, they were highly commended for their poster presentations, judged by visiting external speakers at the REMERGE symposium at Queen's University Belfast (14th Oct 2019). REMERGE is a multidisciplinary team of academic and clinical researchers, with a focus on using regenerative medicine techniques to study and treat a range of clinical conditions.

- A UWS PhD Student was awarded 'runner-up prize for best oral presentation' at the Irish Thoracic Society Galway 2019 meeting and the Certificate of Commendation for her 'elevator pitch' oral presentation at the UWS Research Institutes Health Symposium.
- A UWS PhD Student received the 'Outstanding Student Oral Presentation Award' for her presentation at the Society for Environmental Geochemistry and Health annual meeting.
- 3 members of the BREATH team were awarded the Associate Fellow of the Higher Education Academy (AHEA), June_2021.
- A QUB PI was awarded the International Distinguished Scientist Award
- UWS academic was awarded a prize for her abstract at the Annual UWS Learning Teaching & Research Conference.
- A UWS PhD Student was awarded the 'Star Award' for 'Outstanding Service to Colleagues' – provides key laboratory training for staff and PhD students.
- A QUB staff member was awarded the Star Award (QUB) for her contribution to the EU BREATH programme on chronic obstructive pulmonary disease, supporting 9 members of staff &developing lab protocols.
- BREATH was awarded the 2020 Queen's University Belfast Vice-Chancellor's Prize for Excellence in Research Culture.
- The Eleventh International Cough Symposium was held as a virtual event on the 21st and 22nd of January 2021. Clinicians and scientists gathered for pre-recorded talks, live lectures and poster discussion sessions relating to clinical disease, pathophysiological mechanisms, and emerging treatments for cough. On day 2 of the conference BREATH PhD students presented posters, with one PhD Student winning one of three awards for best abstract.

Appendix IV – Overview of the NWCAM R&I Projects

Overview of the NWCAM R&I Projects						
Thematic Research Area	**R&I Partners**	**Industrial Partner**	**Resources**	**Title**	**Aim**	**Driver**
Advanced Polymers	UU (Jordanstown)	Armstrong Medical	3 PDRA yrs.	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.
			3 PhD yrs.	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.
		Denroy	3 PDRA yrs.	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.
			3 PhD yrs.	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.
		Laser Prototypes Europe (LPE)	4 PDRA yrs. and 3 PhD yrs.	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.
		Causeway Sensors	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 diseases such as sepsis and tuberculosis.	
		axial3D	2 PDRA yrs. and 3 PhD yrs.	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 several 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.

Overview of the NWCAM R&I Projects						
Thematic Research Area	**R&I Partners**	**Industrial Partner**	**Resources**	**Title**	**Aim**	**Driver**
Additive Manufacturing	UU (Magee)	Laser Prototypes Europe (LPE)	2 PDRA yrs. and 3 PhD yrs.	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 was little knowledge of process/material/property interactions and also relatively low productivity levels for metal sintering.
			3 PDRA yrs. and 3 PhD yrs.	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.
			3 PDRA yrs. and 3 PhD yrs.	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.
	LyIT (Lead) and UU (Magee)	Leckey	5 PDRA yrs. and 3 PhD yrs.	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.
Sustainable manufacturing	ITS	Abbott	2.5 PDRA yrs. and 3 PhD yrs.	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 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.
		GSK Stiefel	2.5 PDRA yrs. and 3 PhD yrs.	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 operate a high-volume batch production process facility that utilises several 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.

Overview of the NWCAM R&I Projects						
Thematic Research Area	**R&I Partners**	**Industrial Partner**	**Resources**	**Title**	**Aim**	**Driver**
Nano-manufacturing	Glasgow University	NuPrint	1 PDRA yrs. and 3 PhD yrs.	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.
			2 PDRA yrs. and 3 PhD yrs.	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.
		Causeway Sensors	3 PDRA yrs. and 3 PhD yrs.	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.
		Clyde Biosciences	2 PDRA years	Quantitative force measurements for cardiovascular drug testing	Heart cells are a critical marker for assessment in the development of new drugs. Most toxicology tests are performed in petri dishes which have very different mechanical properties compared to the tissue in vivo. This project will create a new testing environment for testing to be completed quicker and more accurate results provided.	Microfabricated flexible micropillars can be incorporated into a single dish where the traction force is measured. he team at UG have developed a working prototype where 24 and 96 well plates have micropillars incorporated. This allows the performance of multiple experiments in parallel and coupled with an automated microscopy enables 10-20 cells to be measured per well, thus greatly enhance the productivity of the system. This project focuses on the manufacture, refinement and validation of the 96 well platform.

Appendix V – NWCAM Cross-Border Publications

Overview of NWCAM's Cross-Border Publications			
No.	**Title**	**Authors**	**Publication Journal or Conference Title**
1	Application of the anisotropic enhanced thermal conductivity approach to thermal modelling of laser-based powder bed fusion processes using directional correction factors	Sagar H. Nikam , Hao Wu , Ryan Harkin , Shuo Yin , Rocco Lupoi, Justin Quinn , Shaun McFadden	Additive Manufacturing
2	Powder reuse in laser-based powder bed fusion of Ti6Al4V – changes in mechanical properties due to increased oxygen during a top-up regime	Ryan Harkin, Hao Wu, Sagar Nikam, Shuo Yin, Rocco Lupoi, Wilson McKay, Patrick Walls, Justin Quinn and Shaun McFadden,	Materials
3	The application of Vickers micro hardness testing to isostatic polypropylene	Hao Wu, Foram Dave, Mozaffar Mokhtari, Mahmood Ali Muhammad, Richard Sherlock, Alistair McIlhagger, David Tormey, Shaun McFadden	Polymers
4	Effect of tool rotation rate on the properties of friction drilling of 6082-T6 aluminium alloy	Hao Wu, Mark Porter, Richard Ward, Justin Quinn, Cormac McGarrigle and Shaun McFadden	Materials
5	Advanced heat transfer modelling of melt pool dynamics for Selective Laser Melting additive manufacturing process	Sagar H. Nikam, Hao Wu, Ryan Harkin, Shuo Yin, Rocco Lupoi , Justin Quinn , Shaun McFadden	NWCAM Conference
6	Application of micro-Vickers hardness testing to polypropylene	Hao Wu, Foram Dave, Muhammad Mahmood Ali, Mozaffar Mokhtari, Richard Sherlock, Alistair Mcllhagger, David Tormey, Shaun McFadden	NWCAM Conference
7	Crystallisation and Mechanical Properties of Laser Transmission Welded Polypropylene and its Composites	F. Dave, M. Mokhtari, R. Sherlock, A. McIlhagger, D. Tormey	European Structural Integrity Society (ESIS), 2020
8	Effect of Carbon Black on Laser Diode Transmission Welding of Polypropylene	F. Dave, M. Mokhtari, R. Sherlock, A. McIlhagger, D. Tormey	36th International conference of the Polymer processing society (PPS36)
9	Effect of Pigments on Laser Beam Transmission in Diode Laser Transmission Welding in Poly(propylene)	Foram Dave, Mozaffar Mokhtari, M. Mahmood Ali, Richard Sherlock, Alistair McIlhagger, David Tormey	37th International conference of the Polymer processing society (PPS37)
10	Energy Forecasting in a Pharmaceutical Manufacturing Plant	Konrad Mulrennan, Mohamed Awad, John Donovan, David Tormey, Fiona Matthews GSK, William Thompson GSK	NWCAM Conference
11	Finite element analysis of residual stress and warpage in a 3D printed semi-crystalline polymer: Effect of ambient temperature and nozzle speed	Anto Samy, Atefeh Golbang, Eileen Harkin Jones, Edward Archer, Alistair McIlhagger, David Tormey	Elsevier
12	Investigation of the Mechanical Properties of Friction Drilling with 6082-T6 Aluminium Alloy	Hao Wu, Mark Porter, Richard Ward, Justin Quinn, Cormac McGarrigle and Shaun McFadden	MDPI
13	Laser transmission welding of polypropylene composites: Mechanical and Morphological characterisation of lap-joint	Foram Dave, Hao Wu, Mahmood Ali, Mozaffar Mokhtari, Richard Sherlock, Shaun McFadden, Alistair McIlhagger, David Tormey	NWCAM Conference
14	Powder Reuse in Laser-Based Powder Bed Fusion of Ti6Al4V—Changes in Mechanical Properties during a Powder Top-Up Regime	Ryan Harkin, Hao Wu, Sagar Nikam, Shuo Yin, Rocco Lupoi, Wilson McKay, Patrick Walls, Justin Quinn, Shaun McFadden	MDPI
15	Simulated Effect of Carbon Black on High Speed Laser Transmission Welding of Polypropylene with Low Line Energy	M. Mahmood Ali, Foram Dave, Richar dSherlock, Alistair McIlhagger, David Tormey	Frontiers in Materials
16	Supercapacitor electrode fabrication through chemical and physical routes	Parnia Forouzandeh, Priyanka Ganguly, Ravinder Dahiya, Suresh C. Pillai	Elsevier
17	The Direct 3D Printing of Functional PEEK/Hydroxyapatite Composites via a Fused Filament Fabrication Approach	K. Rodzen, S. K. Preetam, A. McIllhagger, M. Mokhtari, F. Dave, D. Tormey, R. Sherlock, B. Meehan, A. Boyd	Polymers
18	The effect of masterbatch pigments on the crystallisation and shrinkage behaviour of polypropylene and High-Density Polyethylene	J. Ullah, E. Harkin-Jones, D. Tormey, F. Dave, R. Sherlock, D. Dixon	International Polymer processing journal

Appendix VIII – NWCAM Research Project Outcomes

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
Advanced Polymers	UU (Jordanstown)/ Armstrong Medical	Development of insulated medical tubing with controlled gas barrier properties.	• Formal Licence Agreement was executed between Ulster University and Armstrong Medical for the developed technology and knowledge incorporated in the AquaVent VTÒ product range (Adult, paediatric and neonatal). • It is expected that the successful collaborative relationship between both partners will continue for many years to come, and discussions were ongoing relating to new follow-on projects.	• Development and commercialisation of a new product (with global market opportunities). • Technology transfer from Ulster University to Armstrong Medical. • Strengthening of collaborative R&D relationships between partners. • Industry-related skills development of academic researchers. • Upskilling of Armstrong Medical staff with regards to manufacturing techniques and material handling technologies. • Knowledge dissemination to the wider HLS sector through academic publications and conference presentations. • Increased competitiveness of the HLS sector through innovation.
	UU (Jordanstown)/ Armstrong Medical	Improving the processability and performance of polypropylene parts.	• Understanding provided on the quality of injection moulded parts when processing conditions change or when additives are included. Examples when include inconsistent shrinkage and mechanical properties with different pigments and/or cooling rates. • Supply chains amended by Armstrong Medical to ensure medical quality replacement options. • Future R&D identified to produce better consistency of pigmented polymers.	• In-depth investigations on how Armstrong Medical applied existing manufacturing processes to specialist polymers. • Supported R&D into end-product which addresses a long-standing limitation of products. • PhD training and development of expertise into product range of polymers, operating on the marketplace.
	UU (Jordanstown)/ Denroy	Development of high-performance (Polyether ether ketone) PEEK Composite.	• One Invention Disclosure has been generated from the WP3 work and was submitted to the Ulster University Innovation Office in September 2021 for consideration of protectable work. • PEEK understanding allows Denroy to expand their current aerospace and healthcare products, by learning about how certain polymers perform, they will be able to develop their manufacturing processes, becoming more efficient and productive as they work to grow their medical device product portfolio.	• Mozaffar Mokhtari was awarded an Associate Fellow of UK Professional Standards Framework for teaching and learning support in higher education. • Cross-border liaison with IT Sligo for sharing of testing equipment and training on new techniques on laser welding • Skills development of staff within Denroy with access to NIBEC, NIACE and UU. • Denroy participated in NWCAM industrial panels and workshops on interests in HLS and future opportunities of growth. • Denroy business diversification in the HLS sector into Bubl and Hero Shield consortium, due to NWCAM connectivity into the sector.

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
	UU (Jordanstown)/ Denroy	Assessment of recyclability of multifunctional PEEK composites.		• Results of both work plans have supported the future R&D direction for Denroy with much publicity and support for the company and for Ulster University. • The partnering has solidified relationships for continued collaboration. • Further partnering developed with ITAINNOVA in Spain for recycling polymers. • Participation of PhD student in NWCAM conference. • Participation of PhD student in NWCAM events for industry and academic knowledge exchange. • Publication of material in high quality REF journals.
	UU (Jordanstown)/ Laser Prototypes Europe (LPE)	Development of advanced materials for additive manufacturing of medical devices and components.	• 3D printing and simulated models of continuous fibre reinforced thermoplastic polymers provided to LPE. • LPE were able to build in their learning to understand and enhance performance properties of the manufactured product. This has resulted in quicker fulfilled customer orders. • Production savings have been realised. • Investment in new software modelling for factory operations has been introduced in LPE.	• Dedicated resource specifically investing LPE production facilities and their outputs. • Electron microscopy and computed tomography skills developed within LPE. • New investment into equipment that is leading edge, due to testing UU equipment before business investment at NIBEC and NIACE. • High quality journal publications. • LPE involvement in academic conferences, exposure to new markets and new companies. • Enhanced technical and scientific skills through demos, illustrations and presentations from UU. • Increased understanding of manufacturing processes to improve complexity of product offering from the business. • Improved reputation of the company's innovation levels through involvement in university research and participation in EU funded project.
	UU (Jordanstown)/ Causeway Sensors	Integration of Injection Moulded Plasmonic Nanostructures into a Biosensor Device (Project A).	• Causeway plan to build on the NWCAM insights to validate their prototype with an aim to launch onto the market within the next 3 years. Validation can only be done through testing the technology with potential users such as big Pharma and biotech companies. • Due to the nature of the IP ownership within NWCAM belonging to the research partner, Ulster University, any proven prototypes will be agreed and accessed under a licensing agreement that will be negotiated directly between the Technology Transfer Office in Ulster University and the CTO in Causeway Sensors.	• Wider partnership developments with several major pharmaceutical companies and other supportive networks such as the Centre for Process Innovation (CPI) in Darlington. • Causeway Sensors is a key partner in the Seagate Led-Innovate UK Strength in Places Smart Nano NI, which will provide substantial funding over a five-year period to help build on their core strengths and plasmonic capabilities as well as that of the Region. • Planning participation in Belfast City Deal in AMIC – Advanced Manufacturing Innovation Centre. • Bespoke PhD training and development. • Supporting company growth and follow-on funding through Catalyst scaling support.

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
				• NWCAM Small grant award allowed Causeway to evolve their product offering.
	UU (Jordanstown)/ axial3D	Characterisation of additive manufacturing polymers for use in advancing surgical practice.	• A vast amount of knowledge and Know-How has been generated from this project. There is potential for intellectual property including patentable subject matter and design rights. • The research is currently being assessed by the technology transfer office, through an Invention Disclosure at Ulster University with potential opportunities for global licencing of the applied technology outputs to Axial3D or other businesses in this sector.	• Skills within Axial3D developed a prototype for glenoid surgical guides and a PEEK 3D printed cranial implant. • Design knowledge of surgical guides were provided to allow the company to explore new business markets. • Detailed market research of commercial guides performed and deep analysis of state of the art provided by the research team. • Detailed patent review based on the current surgical guide landscape provided by NWCAM team. • Assessment of medical device regulatory requirements provided to inform business quality and shape business planning. • Business support via Catalyst Scaling programmes via 'Way to scale'. • TRL shift of the technology from TRL 3 to 5, moving the project closer to market. • Wide dissemination of learning through academic publications. • The collaboration with UU and Axial applied for a Royal Academy of Engineering Fellowship and supported the embedding of UU academic into the company for a continuous exchange of knowledge, guidance and expertise from the University.
Additive Manufacturing	UU (Magee)/Laser Prototypes Europe (LPE)	Optimisation of the laser sintering of metal parts for medical products.	• One Invention Disclosure Form was generated from the WP7. • The IDF was approved and has been given approval of Proof of Concept Stage 1, with developments ongoing into phase 2 PoC which is being supported with Invest NI.	• Skills and understanding of focuses on the laser bed powder of extra low interstitial titanium alloy within LPE. • Cost savings on expensive additive powders is now occurring in LPE, as they know more about the re-use of powders. • Less materials in the production setting has benefits for the environment with higher levels of re-use. • Higher quality products created for customers, creating value for the company due to spatter understanding. • New material follow-on investigations concerning additives in powder for 3D components. • Enhancing Industry 4.0 within the SME base due to improved understanding of material and its application in a range of sectors, including HLS and wider
	UU (Magee)/Laser Prototypes Europe (LPE)	Development of process simulation models for metal laser sintering.	• One Invention Disclosure was generated from the WP8 work and was submitted to the Ulster University Innovation Office in September 2021 for consideration of protectable work.	• The impact of stationery heat point source was shared with LPE, whose skills of staff have developed. • Less waste and associated savings are now experienced due to improved understanding and prediction of the manufacturing processes.

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
			• Advanced heat transfer modelling is now understood within LPE, with a deeper skill set of characterisations of the 3D products LPE can make, and as a result a wider customer offering is now offered for customers. • Production times are now quicker for customers, creating commercial value and excellence of service for their customers.	• University research staff developed COSMOL skills and software integration into their work. • Bespoke MATLAB software was developed and delivered to the project, improving a 2-way exchange of learning and skills enhancement with both partners. • Integration and collaboration with a partner outside NWCAM concerning the project has developed relationships with University of Manchester, NTNU Trondheim, Norway, and University College Dublin. • PhD training and development in entrepreneurship and innovation. • LPE were awarded small grant investments.
	UU (Magee)/Laser Prototypes Europe (LPE)	Development of process simulation models for laser sintering and fused deposition modelling of polymers.	• One Invention Disclosure has been generated from the WP9 work and was submitted to the Ulster University Innovation Office in September 2021 for consideration of protectable work. • New offering of process simulation for additive manufacturing, which is the first of its kind. Such simulations are essential for the development of the process and new materials. Major commercial potential exists for such models.	• New area of investigation for both LPE and UU, with associated skills and expertise in a new investigation area of additive manufacturing • Limitations of additive process understood so less errors are made in real time production which leads to less wastage, cost savings due to improved quality and added value to LPE • Improved LPE morale as production lines are making less errors (which were outside of their control) • Collaboration with UK company for SLS 3D printed sampled for specialised measuring; expanding the expertise that the NWCAM project was invested in • NWCAM ezine marketing involvement • NWCAM event participation • NWCAM investigations and projects greatly supported the future R&D direction for LPE • Longer term business strategy focusing on innovation • NWCAM project gave confidence to invest in new machinery in LPE (3no additive manufacturing machines), which helped extend the range of customers LPE could serve
	LyIT (Lead) and UU (Magee)/ Leckey	Development of a new additive manufacturing machine to enable the use of engineering polymers and larger part builds.	• An operational prototype was delivered at the end of the project to demonstrate embedded sensors in a 3D printed seat. • Leckey/Sunrise Medical senior management team were considering the developments mid 2022 to decide on next steps to evolve the innovations into their product offering. • The NWCAM work has developed an interest in the company to use sensors to further enhance their products to have more bespoke aids that are created for individual needs.	• Cross-border collaboration with a multi-partner approach to the project, allowing for a wider spread of knowledge and expertise • Leckey very pro-active to support NWCAM networking events and were involved in a range of showcasing activities to promote the awareness of R&I within local SMEs in the HLS sector • Leckey staff benefitted from enhanced skills and awareness of sensor technology and 3D printing

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
				• A follow-on investment in a KTP is in application to continue a research study to progress the prototype model closer to market Development of additive manufacturing expertise in North West that didn't exist before NWCAM
Sustainable manufacturing	ITS/ Abbott	Optimising Laser welding process parameters for Polypropylene (PP) bottles.	To investigate Polypropylene (PP) characteristics	• Containers on the production line have less inconsistencies with respect to molecular structure due to marginal variations (pellet moisture, amount of dye used for IR absorption), this improved understanding supports Abbott staff to have higher quality assurance on their production cycles • Improvements on welding cycle times, bonding quality that improve production efficiencies • Reduction in production scrap rates that improves the value add for Abbott.
	ITS/ GSK Stiefel	Minimising energy utilisation for batch production through multivariate scheduling optimisation.	• Two Invention Disclosures Forms from the GSK work were prepared and submitted to IT Sligo's Innovation office. Progress is ongoing and it is hoped that these disclosures will lead to formal UK or Irish patent filings. • Global licensing opportunities and opportunities in knowledge transfer from IT Sligo to GSK globally. The technology in energy modelling and batch scheduling that has been developed can be adapted for licensing to a wide variety of pharmaceutical and other types of manufacturing facilities.	• GSK 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 solutions for different batches. Following the modelling data project GSK estimate between 5% to 10% cost savings in their plant. This saving equates to significant monetary figures due to the huge energy demands on the site. • Reduction of energy consumption supports global efforts to reduce energy usage. • GSK are currently assessing how best to integrate the NWCAM technology into their future sustainability and operational strategy plans. • GSK have implemented the change at Irvine and are rolling out the technology into other sites, GSK is a global company so the scope for the benefits to be replicated are huge. • PhD training and development. • GSK have actively got involved in NWCAM events and networking opportunities. • GSK have linked with local SME's in NWCAM network for supply chain opportunities. • New skill set and demonstrable impact via IT Sligo provides the opportunity to license the technologies into other companies and sectors.
Nano-manufacturing	Glasgow University/ NuPrint	Printing of Electronic Layers and Devices on Flexible substrates.	• NWCAM brought a link into the HLS market for NuPrint. • Linkages into the local ecosystem supported NuPrint reputation as an innovative	• PhD training and development, bespoke modules developed by Catalyst for entrepreneurship and innovation • Technical skills enhanced for NuPrint regarding printed and flexible antenna

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
			company. Company expansion to create the North West Medical Centre, that specialises in locally producing PPE.	• NuPrint small grant award to replicate Uni testing with on-site facilities in Derry/Londonderry • Challenges of smart sensor and integrated with labelling understood, has allowed Nuprint to see the obstacles and avoiding investing in technology that may not have worked with a live info feed. • Nuprint attendance and participation at IEEE international conferences to share his experience and learning within a EU collaborative project • NWCAM ezine features, promoting emerging leaders of Adv manufacturing.
	Glasgow University/ NuPrint	Smart printed RFID Sensor Tags for Health Monitoring.	• RFID antenna designs and optimisations provided to Nuprint, commercial outcomes are being explored with the Innovation Office, testing being applied within medical school before Invention Disclosure being finalised.	• Smart labels research investigations shared with Nuprint, that has allowed the company take time to transition their offering. • NWCAM showcasing event involvement by Glasgow • Glasgow Uni developed new skills in substrate printing and ink options • NuPrint has engaged directly with local NI pharmaceutical company, Randox to explore commercial opportunities for the ongoing research projects. Awaiting prototype to progress discussions • Local healthcare trusts in the Northwest and Belfast, and the NI Blood Service have expressed an interest in the work, prototype is needed to explore potential applications • BEST research team have been showcasing the academically proven research at a variety of online conferences and throughout the UK
	Glasgow University/ Causeway Sensors	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.	(See earlier comments regarding regional investment involvement) • Plasmonic studies by specific software provided to Causeway, increasing the understanding of their testing and results. • Extensive academic contribution involving Causeway as co-authors, this shares the benefits of R&I in HLS, using advanced manufacturing • Increased technical creditability for Causeway for sophistication of work and academic outputs • Access to new equipment (spectrometer) by both partners, enhancing skills and expertise • PhD training and development • NWCAM ezine features of both company and promoting the leaders of tomorrow

Overview of Outcomes of the NWCAM Projects				
Thematic Research Area	**Project Partners**	**Title**	**Commercial outcomes**	**Wider outcomes**
				• Causeway were recipients of small grant investment to develop their research towards commercialisation
	Glasgow University/ Clyde Biosciences	Quantitative force measurements for cardiovascular drug testing	• One invention disclosure relating to the software was submitted to UG's TTO and a Trade Secret Disclosure Form was filed relating to a proprietary algorithm for image acquisition. The trade secret could be licensed to Clyde Biosciences as part of a broader license of software.	• Networking involvement via NWCAM to make new business and academic connections. • Sharing of best practice at internal NWCAM events. • The bioengineering expertise provided by Glasgow Uni have contributed greatly to addressing the unmet needs of their client base in the Pharma and biotech sector and this relationship will continue past the end of the NWCAM program. • NWCAM involvement has supported Clyde Biosciences to focus on their long-term business strategy, building on sustained R&I activities and strategies. • Clyde are now considering what novel biological applications they could add to their current service offering.

Appendix VII – ECME PhD Projects

PhD Ref	Title	Based in	Description	Duration
Cardiac Big Data R&I PhD Programmes				
PhD 3	Development of Multi-Parameter Models for Rapid Diagnosis and Treatment of Cardiovascular Disease	UU/ 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 several diverse biological sources and increase diagnostic yield across several 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. <u>Aims</u> 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.	4 years

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. <u>Aims</u> 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.	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. <u>Aim</u> 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 several 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.	3 years

PhD Ref	Title	Based in	Description	Duration
Smart Wearables founded in Connected Sensor R&I PhD Programmes				
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. <u>Aim</u> 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.	3 years

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. Aims 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.	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. Aims 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.	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. Aims 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.	3 years

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.	3 years
Rapid Homecare Point of Care Diagnostics R&I PhD Programmes				
PhD 1	The development of a new integrated rapid cardiac enzyme sensor for CPR analyses associated with portable defibrillators	UU/ 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. <u>Aims</u> 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.	3 years

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. Aims 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.	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. Aims 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.	4 years

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.	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.	3 years
AAL Home-Based Self-Management R&I PhD Programmes				
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 stoke. In addition, it will be the first project of its kind to embed	3 years

PhD Ref	Title	Based in	Description	Duration
			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. 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.	
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.	4 years

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. 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.	3 years

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. <u>Aims</u> 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.	3 years
Self-Management/ Rehab R&I PhD Programmes				
PhD 4	In vitro cellular models to study the effects of waveform stimulation of cardiac tissue	UU/ 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). <u>Aims</u> 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.	3 years

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. <u>Aim</u> 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.	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. <u>Aims</u> 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.	3 years

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.	3 years
PhD 8	Ambient Assisted Living for Cardiovascular Disease Exercise Compliance,	DkIT	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?	4 years

Appendix VIII – ECME Project Cross-Border Publications

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
1	Dublin City University	Reactive Oxygen Species (ROS), Intimal Thickening, and Subclinical Atherosclerotic Disease	Denise Burtenshaw1†, Michael Kitching2†, Eileen M. Redmond3, Ian L. Megson4 and Paul A. Cahill 1* 1 Vascular Biology & Therapeutics, School of Biotechnology, Dublin City University, Dublin, Ireland, 2 School of Chemistry, Dublin City University, Dublin, Ireland, 3 Department of Surgery, University of Rochester, Rochester, NY, United States, 4 Centre for Health Science, UHI Institute of Health Research and Innovation, Inverness, United Kingdom	2019
2	Ulster University	Unobtrusive Measurement of Upper Extremity Velocity During Post-Stroke Rehabilitation Exercises	Idongesit Ekerete[1], Chris Nugent[1], Oonagh M Giggins[2], Matias Garcia-Constantino[1], James McLaughlin[3]. [1] School of Computing, Ulster University. [2] Dundalk Institute of Technology, Rep. of Ireland. [3]NIBEC, Ulster University.	2019
3	Ulster University	Unobtrusive Sensing Solution for Post-stroke Rehabilitation	Idongesit Ekerete[1], Chris Nugent[1], Oonagh M Giggins[2], James McLaughlin[3]. [1] School of Computing, Ulster University. [2] Dundalk Institute of Technology, Rep. of Ireland. [3]NIBEC, Ulster University.	2020
4	Ulster University	Unobtrusive Monitoring of Home-Based Post-Stroke Rehabilitation Exercises Using Heterogeneous Sensors	Idongesit Ekerete[1], Chris Nugent[1], Oonagh M Giggins[2], Ian Cleland[1], James McLaughlin[3]. [1] School of Computing, Ulster University. [2] Dundalk Institute of Technology, Rep. of Ireland. [3]NIBEC, Ulster University.	2020
5	Ulster University	Detection and Categorisation of Multilevel High-sensitivity Cardiovascular Biomarkers from Lateral Flow Immunoassay Images via Recurrent Neural Networks	Min Jing (UU), Donal McLaughlin (UCL), David Steele (BioColor Ldt), Sara McNamee (UU), Brian MacNamee (UCD), Patrick Cullen(UU), Dewar Finlay (UU) and James McLaughlin (UU)	2019
6	Ulster University	Enhance Categorisation of Multilevel High-Sensitivity Cardiovascular Biomarkers from Lateral Flow Immunoassay Images via Neural Networks and Dynamic Time Warping	Min Jing (UU), Brian Mac Namee (UCD), Donal McLaughlin (UCL), David Steele (BioColor Ldt), Sara McNamee (UU), Patrick Cullen(UU), Dewar Finlay (UU) and James McLaughlin (UU)	2020
7	Ulster University	ST Changes Observed in Short Spaced Bipolar Leads Suitable for Patch Based Monitoring	Michael Jennings (UU), Daniel Guldenring (HTWB), Raymond Bond (UU), Ali Rababah (UU), Jim McLaughlin (UU), Dewar D Finlay (UU)	2020
8	Ulster University	Coefficients for the Derivation of Posterior and Right Sided Chest Leads from the 12-lead ECG (abstract accepted)	Michael Jennings (UU), Ali Rababah (UU), Pardis Biglarbeigi (UU), Rob Brisk (CAH/UU), Daniel Guldenring (HTWB), Jim McLaughlin (UU), Dewar D Finlay (UU)	2020
9	University of the Highlands and Islands	Digital technologies for risk factor modification in patients with cardiovascular disease: a systematic review and meta-analysis.	Adewale S. Akinosun1, Robert Polson2, Yohanca Diaz4, Hannes De Kock1, Lucia Carragher4, Stephen J. Leslie3, Mark Grindle1. 1Digital Health, Centre for Health Science, Institute of Health Research and Innovation, University of the Highlands and Islands, Inverness, UK (PhD Researcher and Senior Lecturer); 2Highland Health Science Library, University of the Highlands and Islands, Inverness, UK (Subject Librarian); 3Cardiac Unit, NHS Highland, Inverness, UK (Consultant Cardiologist, Professor); 4School of Health and Science, Dundalk Institute of Technology, Dundalk, RoI (PhD Researcher and Senior Research Fellow).	2020

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
10	University of the Highlands and Islands	Digital storytelling for cardiovascular disease risk factor modification: a scoping review.	Adewale S. Akinosun1, Robert Polson2, Noreen Grant1, Ania Zubala1, David Coyle4, Stephen J. Leslie3, Mark Grindle1. 1Digital Health, Centre for Health Science, Institute of Health Research and Innovation, University of the Highlands and Islands, Inverness, UK (PhD Researchers, Research Fellow and Senior Lecturer); 2Highland Health Science Library, University of the Highlands and Islands, Inverness, UK (Subject Librarian); 3Cardiac Unit, NHS Highland, Inverness, UK (Consultant Cardiologist, Professor); 4School of Computer Science, Science Centre, University College Dublin, Belfield, Dublin, Republic of Ireland (Associate Professor)	2020
11	Dublin City Unversity	Reactive Oxygen Species (ROS), Intimal Thickening, and Subclinical Atherosclerotic Disease	Denise Burtenshaw(DCU) Michael Kitching2†, Eileen M. Redmond3, Ian L. Megson (UHI) and Paul A. Cahill1*	2020
12	Dundalk Institute of Technology	Enablers and obstacles to implementing remote monitoring technology in cardiac care _ A report from an interactive workshop	Yohanca D. DKIT David McQuid Oonagh Giggins Paul Beaney (UU)	2019
13	Ulster University	Novel Hybrid Method for Interpolating Missing Information in Body Surface Potential Maps	Ali S.Rababah Msca (UU) Raymond R.BondPhD Khaled RjoobMsc DanielGuldenringPhD (Hochschule für Technik und Wirtschaft, Berlin, Germany) JamesMcLaughlinPhD Dewar D.FinlayPhD	2019
14	Ulster University	Interpolating Low Amplitude ECG Signals Combined with Filtering According to International Standards Improves Inverse Reconstruction of Cardiac Electrical Activity	Ali S.Rababah (UU) Khaled RjoobMscLaura Bear (Univerity of Bordeaux) JamesMcLaughlin Dewar D.Finlay	2019
15	Ulster University	Effects of Interpolation on the Inverse Problem of Electrocardiology	Y S Dogrusoz, L R Bear,(University of Bordeaux) J Bergquist,3 R Dubois,2 W Good,3R S MacLeod,3 A Rababah,(Ulster University) and J Stoks5	2019
16	Ulster University	Towards explainable artificial intelligence and explanation user interfaces to open the 'black box' of automated ECG interpretation	Khaled Rjoob, MSc1, Raymond Bond, PhD1, Dewar Finlay, PhD1, Victoria McGilli-gan, PhD2, Stephen J Leslie, PhD3, Ali Rababah, MSc1, Aleeha Iftikhar, MSc1, Daniel Guldenring, PhD4, Charles Knoery, MSc3, Anne McShane, MSc5, Aaron Peace, PhD6	2021
17	Ulster University	Machine learning techniques for detecting electrode misplacement and interchanges when recording ECGs: A systematic review and meta-analysis	Khaled Rjoob, MSc a,⁎, Raymond Bond, PhDa, Dewar Finlay, PhDa, Victoria McGilligan, PhDb, Stephen J. Leslie, FRCP, PhDc, Ali Rababah, MSc a, Daniel Guldenring, PhDd, Aleeha Iftikhar, MSc a, Charles Knoery, MBChB c, Anne McShane, MSc e, Aaron Peace, MB BCh BAO, PhDf	2020
18	Ulster University	Machine Learning Improves the Detection of Misplaced V1 and V2 Electrodes During 12-Lead Electrocardiogram Acquisition	Khaled Rjoob1, Raymond Bond1, Dewar Finlay1, Victoria McGilligan2, Stephen J Leslie3, Aleeha Iftikhar1, Daniel Guldenring4, Ali Rababah1, Charles Knoery3, Aaron Peace5	2019
19	Ulster University	The effect of interpolating low amplitude leads on the inverse reconstruction of cardiac electrical activity	Ali S. Rababah1, Laura R. Bear2, Yesim Serinagaoglu Dogrusoz3, Wilson Good4, Jake Bergquist4, Job Stoks5, Rob MacLeod4, Khaled Rjoob1, Michael Jennings1, James Mclaughlin1, Dewar D. Finlay1	2021

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
20	Ulster University	An Adaptive Laplacian Based Interpolation Algorithm for Noise Reduction in Body Surface Potential Maps	Ali S Rababah, Dewar D Finlay, Daniel Guldenring, Raymond Bond, James D McLaughlin	2018
21	Ulster University	39 Performance of a computer model to detect misplaced V1 and V2 electrodes on the 12-lead ECG for three different types of patients	K Rjoob1, R Bond1, D Finlay1, V McGilligan2, S Leslie3, A Iftikar1, D Guldenring4, C Knoery5, A Rababah1, A Peace6	2019
22	Ulster University	Regression or Pseudo-Inverse – Which Method Should be Preferred When Developing Inverse Linear ECG-Lead Transformations?	Daniel Guldenring1, Ali Rababah2, Dewar D Finlay2, Raymond R Bond2, Alan Kennedy2, Michael Jennings2, Khaled Rjoob2, James McLaughlin2	2020
23	Ulster University	Data Driven Feature Selection and ML to Detect Misplaced Chest Electrodes	Khaled Rjoob, RR Bond, D Finlay, V. E. McGilligan, Stephen James Leslie (UHI) Aleeha Iftikhar, D Guldenring (Hochschule für Technik und Wirtschaft, Berlin, Germany), Ali Rababah (Ulster University) Charles Knoery, Anne McShane, Aaron Peace	2020
24	UHI / DKIT	State of play of wearable devices for the measurement of Heart Rate: A systematic review of the accuracy of wrist-worn technologies.	David Muggeridge (UHI) Oonagh Giggins (DKIT)	2019
25	University of the Highlands and Islands	Clinical Application of Physical Activity Monitoring in Patients with Cardiovascular Implantable Electronic Devices (CIEDs)	K. Callum, D.J.Muggeridge, O.M.Giggins, D.Crabtree, T.Gorely & S.J.Leslie	2020
26	University of the Highlands and Islands	Oxidative stress and inflammation in the development of cardiovascular disease and contrast induced nephropathy	Karla Cervantes-Gracia1,*, Khuram Raja2,*, Daniel Llanas-Cornejo3, James N. Cobley2, Ian L. Megson2, Richard Chahwan1 , Holger Husi2,4	2020
27	University of the Highlands and Islands	Establishing the efficacy of interventiosn to improve health literacy and health behaviours: a systematic review	Ronie Walters (UHI), Stephen Leslie (UHI), Rob Polson (UHI), Tara Cusack (UCD), Trish Gorely (UHI)	2020
28	Ulster University	Machine Learning Approach to Assess the Performance of Patch Based Leads in the Detection of Ischaemic Electrocardiogram Changes	Michael Jennings, Pardis Biglarbeigi, Raymond Bond, Rob Brisk, Daniel Guldenring, Alan Kennedy, James McLaughlin, Dewar Finlay	2020
29	University of the Highlands and Islands	Health Literacy for Cardiac Rehabilitation: An Examination of Associated Illness Perceptions, Self-Efficacy, Motivation and Physical Activity	Ronie Walters (UHI), Stephen Leslie (UHI), Jane Sixsmith (NUIG), Trish Gorely (UHI)	2020
30	University of the	Digital Narrative Approach (DNA): A Behavioural Risk Factor Modification Research in People Living with Cardiovascular Disease	Akinosun, A.S1; Walters, R1; Kelly, J2; Leslie, S1; Grindle, M1. 1. University of the Highlands and Islands1 2. Dundalk Institute of Technology	2020

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
	Highlands and Islands			
31	Dundalk Institute of Technology	Delivering Cardiac Rehabilitation Remotely using a Digital Health Platform - A Protocol for a Pragmatic Randomized Controlled Trial	Giggins O.M.1, Doyle J.1, Moran O.1, Smith S.1, Muggeridge D.2, 3, Crabtree D.3, Fraser M.3 1. NetwellCASALA, Dundalk Institute of Technology, Co. Louth, Ireland2. School of Applied Sciences, Edinburgh Napier University, Edinburgh, Scotland. 3. Division of Biomedical Sciences, University of the Highlands and Islands, Inverness, Scotland.	2020
32	Dundalk Institute of Technology	A Medication App for Older People Attending an HF Clinic	Diaz-Skeete, Y.1 & Carragher, L.1 1. Dundalk Institute of Technology Marshes Upper, Dundalk, Co. Louth, Ireland 2. University of the Highlands and Islands, Centre for Health Science, IV2 3JH Inverness, UK. 3. School of Computing, Jordanstown Campus, Ulster University, UK.	2020
33	University of the Highlands and Islands	An Ethnography of Home in a Pandemic	Hughes, K1 Diaz, J2 Grindle, M1 Sheng, Y2 1. University of the Highlands and Islands 2. Dundalk Institute of Technology	2020
34	University of the Highlands and Islands	Assessing the Usability and Adherence to Wearable Technology and the RADAR-base Platform in online Home-based Exercise (Pilot Study)	Fraser, M.1, Crabtree, D.2 Muggeridge, D.3, Gorely, T.4, Giggins, O.51. University of the Highlands and Islands 2. University of the Highlands and Islands	2020
35	Ulster University	Use of Carotid Intima-Media Thickness and Plaque Volume to predict single or multi-vessel Coronary Artery Disease	Owen, KS.12, Menown, IB.2, Jennings, M.1, Skillen, K-L.1, Zhang, X.1,2, Regan, B.3, Burtenshaw, D3, Oâ€™Maolmhuaid, F.3 1. Ulster University 2. Southern Health and Social Care Trust 3. Dublin City University	2020
36	Ulster University	Data Analytics for Healthcare	Jing, M.1, Mac Namee, B.2, Bond, R.1 , Brisk, R.3 , Finlay, D.1 , McLaughlin, J. 1 1. NIBEC, School of Engineering, Ulster University, UK. 2. School of Computer Science, University College Dublin, Republic of Ireland. 3. Southern Health and Social Care Trust, Northern Ireland	2020
37	Ulster University	The Selection of Nanomaterials for Cystatin C Lateral Flow Assay Detection	Zhang, X. 1,2, Fishlock, S. 1, Regan, B.3, Burtenshaw, D.3, Ã“ Maolmhuaidh, F.3, Sharpe, P. 2, McLaughlin, J. 1. NIBEC, School of Engineering, Ulster University, UK 2. Southern Health & Social Care Trust, UK 3. Dublin City University, Ireland	2020
38	University College Dublin	Study of Multimodal Data Warehouse Assuring Privacy and Security on Cardiology Datasets and their Sources	Thantilage, Ranul, Kechadi, Tahar, Nhien-An, Le-Khac University College Dublin ranul.thantilage@ucdconnect.ie Thantilage, Ranul.1, Kechadi, Tahar.1, Le-Khac, Nhien-An.1, Owen, Kathryn.2 1. University College Dublin, Ireland 2. Ulster University and Southern Health and Social Care, Northern Ireland	2020
39	Ulster University	The Efficacy of the Hybrid Interpolation method in Reconstructing the Missing Data in Body Surface Potential Maps	Rababah, A S.1, Bond, R.2, Rjoob, K.2, Gludenring, D3, McLaughlin, J1, Finlay, D1 1. School of Engineering, Ulster University, United Kingdom of Great Britain and Northern Ireland 2. School of Computing, Ulster University, United Kingdom of Great Britain and Northern Ireland 3. Hochschule fÃ¼r Technik und Wirtschaft, Berlin, Germany	2020

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
40	Ulster University	Heart Attack Detection via Computational Electrocardiographic Analysis	Jennings, M.1, Regan, Brian.2, Owen, K.1, Zhang, X.1, Josephine McIvor, M.1, Burtenshaw, D.2, Ã“ Maolmhuaidh, F.2, McLaughlin, J.1, Finlay, DD.Â¬1 1. Ulster University, UK 2. Dublin City University, Ireland	2020
41	Dundalk Institute of Technology	A Data-driven View of Engagement with Home-Based Digital Self-Management System for Older Adults with Chronic Conditions	Sheng, Y.1, Doyle, J.1, Jaiswal, R.1, Bond, R.2 1. Dundalk Institute of Technology, Marshes Upper, Dundalk, Co. Louth, Ireland 2. School of Computing, Jordanstown Campus, Ulster University, UK.	2020
42	Ulster University	Automating Electrochemical Detection for Centrifugal Microfluidics	Regan, B.1, Jennings, M.2, Collins, D.1, 1. School of Biotechnology, Dublin City University 2. School of Engineering, Ulster University	2020
43	University of the Highlands and Islands	The Impact of Health Literacy on Health Behaviours in Cardiac Rehabilitation	Walters, R.,1 Leslie, S.J.,1,2 Poulson, R.,1 Cusack, T.,3 Sixsmith, J.,4 Gorely, T1. 1. University of the Highlands and Islands 2. Cardiology Department, NHS Highlands 3. University College Dublin 4. National University Ireland Galway	2020
44	University of the Highlands and Islands	Why Is COVID-19 More Severe in Patients With Diabetes? The Role of Angiotensin-Converting Enzyme 2, Endothelial Dysfunction and the Immunoinflammatory System	Jacob Roberts1, Antonia L. Pritchard1, Andrew T. Treweeke1, Adriano G. Rossi2, Nicole Brace1, Paul Cahill3, Sandra M. MacRury1, Jun Wei1 and Ian L. Megson1	2021
45	Ulster University	Data Mining and Fusion of Unobtrusive Sensing Solutions for Indoor Activity Recognition	Idongesit F. Ekerete[1], M. Garcia-Constantino[1], Yohanca Diaz[2], Oonagh M. Giggins[2], M. A. Mustafa[3], Alexandros Konios[4], Pierre Pouliet[5], Chris D. Nugent[1], *Member, IEEE*, Jim McLaughlin[6], *Member, IEEE.* 1. School of Computing, Ulster University, BT37 0QB, Northern Ireland, United Kingdom. 2. Dundalk Institute of Technology, NetwellCASALA, Dundalk Institute of Technology, Rep. of Ireland. 3. Department of Computer Science, The University of Manchester, United Kingdom / imec-COSIC, KU Leuven, Leuven, Belgium. 4. School of Computing, Electronics and Mathematics, Coventry University Coventry, United Kingdom. 5. Université de Limoges, Limoges, France. 6. J. McLaughlin, NIBEC, Ulster University, BT37 0QB, Northern Ireland, United Kingdom	2020
46	Ulster University	COVID-19 modelling by time-varying transmission rate associated with mobility trend of driving via Apple Maps	Min Jing (UU), Kok Yew Ng (UU), Brian Mac Namee (UCD), Pardis Biglarbeigi(UU), Rob Brisk(STH), Raymond Bond(UU), Dewar Finlay (UU) and James McLaughlin (UU)	2021
47	Ulster University	Code-Free Cloud Computing Service to Facilitate Rapid Biomedical Digital Signal Processing and Algorithm Development	Michael R.Jennings (UU), ColinTurner (UU), Raymond R.Bond (UU), Alan Kennedy (UU), Ranul Thantilage (UCD), Mohand Tahar Kechadi (UCD), Nhien-An Le-Khac (UCD), James McLaughlin (UU), Dewar D.Finlay (UU)	2021
48	Ulster University	Coefficients for the Derivation of an ST Sensitive Patch Based Lead System from the 12 Lead Electrocardiogram	Michael R Jennings (UU), Ali Rababah (UU), Daniel Gueldenring (Hochschule Kempten), James McLaughlin (UU), Dewar D Finlay (UU)	2021

ECME Cross-border Publications				
No	**Name of Lead Institution**	**Title of Paper**	**Authors & Organisations**	**Publication Year**
49	Ulster University	A Novel Method for Quantitative Analysis of C-Reactive Protein Lateral Flow Immunoassays Images via CMOS Sensor and Recurrent Neural Networks	Min Jing (UU), Donal McLaughlin (UCL), Sara McNamee (UU), Shasidran Raj (UU), Brian Mac Namee (UCD), David Steele (BioColor Ldt), Dewar Finlay (UU) and James McLaughlin (UU)	2021

Appendix IX – CPM Industry Involvement

Voscuris	Cooperating with Research Institutes The team at Voscuris engaged with all the research institutions involved in the CPM to identify areas where the existing Voscuris technology could be deployed to support the research projects, and where new solution development could be targeted. This led to two main projects with research partners within UU/WHSCT, where exposure to the clinical environment and advice on the latest developments in the problem space were provided to the Voscuris team. 1. *RC3 Acute Kidney Injury – Decision Support Tool for Suspected AKI*. This project addressed the challenge of earlier identification of risk factors that could lead to AKI. Activities included a site visit, problem mapping exercise, solution ideation and wireframe prototype development. 2. *RC1 PCI in Myocardial Infarction – ECG Interpretation App*. This project addressed the challenge of skill atrophy among healthcare staff who are required on occasion to interpret and act on ECG traces. The project team proposed a solution where a mobile based training app could maintain engagement with users through application of gamification techniques, human computer interaction (including application of AI decision support tools), social interaction, and adaptive perpetual learning. Activities included problem mapping, solution ideation, wireframing, and a user survey. Voscuris also made several funding applications for projects in collaboration with WHSCT, CTRIC, and LYIT, and provided consultancy support to the central technology team. Participating in cross-border, transnational or interregional Research projects RC4 Unscheduled Care in Diabetes The Voscuris team have participated consistently with the RC4 Unscheduled Diabetes Care project, including attending the Primary Care Diabetes Society Conference in 2018, and the extended team meeting hosting in Inverness in 2019. Initial support was provided for research ethics applications before post-doc recruitment, and later an industry perspective throughout the project. The expectation was that Voscuris would support the second phase of the research projects through an intervention study, where an app for either training users or a decision support tool for treat and leave implementation would be developed. However, due to delays in the project and the impact of Covid this will not occur within the timeframe of the CPM. RC2 Emergency Surgery – Questionnaire Development. The Voscuris team engaged with the RC2 research team and CPM central technology team to understand the requirements for creation of an emergency surgery registry as part of eSOAP (LUH/LYIT). Due to product readiness limitations, the RC2 project progressed with an existing solution (RedCap). However, the Voscuris team were able to use the registry questionnaire as a use case for gaining user feedback and further development of mobile data collection tools, with the potential to replace the RedCap solution if suitable. Insight gained from this collaboration informed the later development of the Voscuris Covid Note app, a tool for enabling patients experiencing post-covid syndrome to record their symptoms. Collaboration with LYIT has led to further funding applications and placement/supervision support for a PhD student (non-CPM).

NICRS	NICRS primarily engaged with the following research clusters: • Emergency Surgery Research Cluster • Diabetes Research Cluster • Acute Kidney Research Cluster NICRS Ltd are based in Derry/Londonderry (NI). They engaged with each research cluster to understand their protocols to prepare the correct ethics and governance needs. This has also led to preparation of all the vast amount of accompanying documentation required for each ethical approval, which is different in each jurisdiction. Participation in the CPM has provided significant benefit to NICRS particularly as an SME. The Centre has provided a structure for access to clinical and research expertise, and insight into unmet clinical needs across several conditions. NICRS has also been able to foster relationships with project participants that will be maintained through collaborations beyond the CPM.
Optum	Optum delivered a two-day workshop for CPM staff at Ulster University (6/7 March 2019): • Purpose: Deep dive into the Architecture / Design of database: Brief discussion on GDPR, patient confidentiality etc. but we may need a dedicated workshop for this topic • Output: Roadmap of how Optum can contribute going forward. Specifically, it was decided that Optum would partner with LYIT to provide a reference architecture for a data and analytics platform to meet the needs of the program now and into the future. Particular focus on what a production ready hardened environment might look like. • Over a period of several months Optum engaged directly with LYIT to build the reference architecture as outlined. This involved weekly working sessions and SME design hours provided as in-kind contribution. The team delivered the reference architecture as agreed. CPM invited Senior Industry thought Leaders from Optum to present at the annual scientific TMED 2019 conference. 6 Optum staff attended, and the Optum SVP and Technology Fellow presented on his work on AI as well as two other Optum staff. Optum provided Sr AI SMEs to particular clusters for brainstorming workshops and as peer reviewers as needed. For example, collaboration with Kongfatt on Dementia cluster. Optum participated in the CPM Management Team as an advisory partner where relevant. Meetings were held quarterly and were attended by an Optum representative. In addition, David met with the CPM PM informally on a monthly basis for a period of time to ensure that any opportunities to participate / advise on research cluster activities was not missed. Over a period of several months Optum engaged directly with LYIT to build the reference architecture as outlined. This involved weekly working sessions and SME design hours provided as in-kind contribution. The team delivered the reference architecture as agreed. <u>Emergency Surgery Cluster</u> • Optum worked with LUH & LYIT over several weeks on opportunities for the application of AI/ML in the area of decision support for critical care pathways. Output from this work was firm guidance to LUH on the specific areas of opportunity and recommendations on the types of data required. Focus on long tern gain through achieving near term success. • Optum provided consultation services to LUH on other potential ideas from LUH in the area of decision support systems for critical care pathways • Optum collaborated with LYIT & LUH in providing technical SMEs in the area of business intelligence and reporting and provided recommendations on areas of opportunity for LUH for achievable high impact dashboarding.

	Cardiovascular & Acute Kidney Injury Cluster [Diabetes meeting? • Optum conducted several exploratory meetings with cardiovascular cluster leads Raymond Bond & Victoria McGilligan and with the Acute Kidney Injury cluster lead Gary Doherty mid-2020 and provided some info on how we could help – but the clusters did not identify specific tasks that could benefit from Optum's support. Through the work with the CPM partners, specifically LUH and LYIT, Optum gained knowledge on health services data and associated architecture. Optum also gathered information on ongoing research projects within Ulster University that aligned with work ongoing within Optum. This may facilitate the building of potential networks within specific disease areas (e.g., dementia). The collaboration with the contributors from the faculty of Computing has led to several additional positive outcomes: • Optum participation on UU's Faculty of Computing's Computing Employer Advisory Board (CEAB). • Optum's contribution as Industry partner on the cross-border AI NOW initiative with UU and LYIT • Optum have developed closer collaboration with Faculty members in the areas of Computing and AI leading to Optum employees participating on UU programs and providing speakers for MSc classes. • Optum invited Dr Brian Garner to the Letterkenny campus for a site tour and to present on the higher learning opportunities at UU. • Optum invited members of UU, LYIT and the CPM project to tour the Dublin facility where demos on some of the advanced research and development happening at Optum were done.
Randox	Randox assisted the project in the following manner: • Randox met with staff compiling the database at the start of the project to provide knowledge as to the type and detail of information that should be provided including clinical, final diagnosis, details of jobs they have had throughout their life, to assist with the analysis • Randox also stressed the importance of a double entry system to reduce the risk of errors from manual entry of data. • Randox spoke with the cardiac cluster and shared results from a similar biomarker study performed in another hospital in N. Ireland. Randox suggested that Heart-type fatty acid-binding protein should also be measured as it is raised earlier than high sensitivity troponin. Randox asked for details of the 8 biomarkers the cardiac cluster were interested in (an NDA was already in place); however, this was not forthcoming. Randox shared details of the biochip panels with biomarkers for testing the samples collected as part of this study. Testing of samples collected was not requested by the cardiac cluster. • For the AKI & CKD Cluster, Randox tested in total 279 serum and 197 urine samples on the following biochip arrays; – CKD I (FABP-1, MIP1, sTNFR1, sTNFR2 in plasma) – CKD II (CRP, NGAL, C3a desArg, Adiponectin in plasma) – AKI Array (Clusterin, NGAL, Cystatin C, KIM-1 in urine). • CKD I and II arrays were run on the Randox Evolution™ instrument and the AKI array was run on the Evidence Investigator™ instrument. Cystatin C was run on the Randox Imola. The analysis was completed between the Randox Teoranta site in Dungloe and at Randox Clinical Laboratory Services in Antrim. The results were reported back to the team at UU. • Randox reviewed the results from the AKI project and provided feedback on patient recruitment and sample processing procedures to ensure future improvements. • Randox requested to analyse and review the anonymized databases from all clusters.

Appendix X – Renewable Engine Cross-Border Publications

Publications with Cross-border Authorship		
Title	**Authors**	**Journal/Conference**
A techno-economic analysis of small-scale	Sean O'Connor, Suresh C Pillali Ehiaze Ehiman, Aaron Black	European Biomass Conference and Exhibition, May 2019, Lisbon
An Investigation of the Potential Adoption of Anaerobic Digestion for Energy Production in Irish Farms	Sean O'Connor, Ehiaze Ehimen, Suresh C. Pillai, Niamh Power, Gary A. Lyons, John Bartlett	Environments
Biogas production from small-scale anaerobic digestion plants on European farms	O'Connor S, Ehimen E, Pillai S.C, Black A, Tormey, Bartlett J	Renewable and Sustainable Energy Reviews
Economic and Environmental Analysis of Small-Scale Anaerobic Digestion Plants on Irish Dairy Farms	Sean O'Connor, Ehiaze Ehimen, Suresh C. Pillai, Gary Lyons, John Bartlett	Energies
Effect of chalcogens (S, Se, and Te) on the anatase phase stability and photocatalytic antimicrobial activity of TiO2	Snehamol Mathew, Priyanka Ganguly, Vignesh Kumaravel, John Harrison, Steven J. Hinder, John Bartlett, Suresh C. Pillai	Materials Today Proceedings
Indium doped TiO2 photocatalysts with high temperature anatase stability	Vignesh Kumaravel, Stephen Rhatigan, Snehamol Mathew, John Bartlett, Michael Nolan, Steven J. Hinder, Preetam K. Sharma, Anukriti Singh, J. Anthony Byrne John Harrison, Suresh C. Pillai	The Journal of Physical Chemistry
Pyrolysis kinetic modelling of abundant plastic waste (PET) and in-situ emission monitoring	Ahmed I. Osman, Charlie Farrell, Alaa H. Al-Muhtaseb, Ahmed S. Al- Fatesh, John Harrison, David W Rooney	Industrial & Engineering Chemistry Research
Sintering and Densification of Fibre Reinforcement in	David Castellanous, Peter Martin, Joseph Butterfield, Mark McCourt, Mark Kearns, Patrick Cassidy	Procedia Manufacturing
Technical challenges and opportunities in realising a circular economy for waste photovoltaic modules	C.C. Farrell, A.I. Osman, R. Doherty, M. Saad, X. Zhang, A. Murphy, J. Harrison, A.S. M. Vennard, V. Kumaravel, A.H. Al-Muhtaseb, D.W. Rooney	Journal: Renewable and Sustainable Energy Reviews
Submitted but not yet published		
Role of viscosity on optimum polymer-fibre interaction during rotational moulding sintering	D. Castellanos, M. McCourt, P. Martin, M. Kearns, J. Butterfield and P. Cassidy	ESAFORM 2022
Polymer-fibre characterisation and its role in optimum sintering and densification in rotational moulding		Polymer Processing Society 36th
Densification of Fibre- Reinforced Composite Polymers for the Rotational Moulding Process		International Conference on Manufacturing of Advanced Composites 2021

Appendix XI - Renewable Engine PhD Projects

The project had 12 PhD students, 10 of which were aligned to company projects whilst 2 undertook research which was directed towards the sectoral research goals of the academic partners with Renewable Energy for Advanced Manufacturing, as follows:

1. Development of New Nanocatalysts for the Direct Conversion of Biogenic Carbon Dioxide to Sustainable Fuels (South West College): The aim of this project was the development of new nanocatalysts for the direct conversion of biogenic carbon dioxide (CO2) to "drop-in" fuels in the gasoline range (C8-C12), resulting in a sustainable production route. Hydrogen will be utilised from renewable energies and CO2 will be directly converted, which offers an attractive route for the efficient utilisation of CO2 as a renewable feedstock.
2. Physiochemical Characterisation and a Kinetic Investigation of Constituents Found in First-Generation (c-Si) Photovoltaic Modules (South West College): This project focused 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

The table overleaf provides an overview of the 10 research projects undertaken with an industry partner.

Renewable Engine Industry Project Overview			
Company	**Project area**	**Institution**	**Info on project**
Research Theme: Energy Generation			
Kingspan Water & Energy	Rotomoulding	QUB	*Development of Lightweight Rotomoulded Multi-Layer Structures for Off-Shore Energy Generation* The development of advanced manufacturing processes for large, low-cost and lightweight structural components is essential to the future success of the marine energy generation sector. 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.
Platinum Tanks	Rotomoulding composites	QUB	*Development of Hybrid Rotomoulded Composite Structures for Solar Panel Frames Queen's University Belfast & 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. The outputs will help to contribute to the design of a prototype tool which will be used to produce hybrid components for such solar applications.
Rotosim	Rotomoulding simulation	QUB	*Simulation of the Advanced Manufacturing of Multi-layer Rotomoulded Structures for the Renewable Energy Sector* The aim of this project is the development of a multi-layer rotational moulding simulation and modelling program specifically for the advanced manufacturing of renewable energy sector structures. Low-cost tooling in the rotational moulding process makes multi-layer rotomoulded structures very attractive as an alternative to steel constructions.
Organic Power	Small anaerobic digesters	ITS	*Developing Small-Scale Off-Grid Renewable Power through Anaerobic Digestion* The benefits of anaerobic digestion (AD) are widely recognised but traditional systems have a relatively high fixed-cost precluding their wider use. This project will 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.
Katus Technologies	LED / Photocat	ITS	*Developing Band-Gap Tuneable Photocatalysts for the use of Energy Efficient LED Lamps* Energy efficient LED lights, instead of the conventional use of UV light, is investigated as a sustainable technology for environmental and energy applications by way of photocatalysis. This project aims to develop photocatalysts that can yield high efficiency under energy efficient light sources (such as LED) and extend their application to room interiors where there is relatively poor lighting/illumination.
Caley Ocean Systems ASC Ltd	Gravitational potential energy storage	UoS	*Realising Heavy Lift Operations from Floating Vessels for Offshore Wind* 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 & Maintenance carried out by floating vessels rather than expensive and slow jackup 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.

Renewable Engine Industry Project Overview			
Company	**Project area**	**Institution**	**Info on project**
Research Theme: Energy Storage			
B9 Energy	Compressed air energy storage	SWC/QUB	*Near Isothermal Liquid Piston Research and Innovation* Liquid piston compression can offer an alternative to standard technologies with improved efficiency gains, reduced system complexity and reduced cost. The main objective of this research is to develop a novel isothermal compressed air energy system (CAES) using liquid piston technology.
Soltrophy	Solar collectors	UoS	*Incorporating Heat Storage inside Twin-Walled Evacuated Tube Solar Collector* 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. This will be achieved using phase-change materials or materials with a 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.
Doosan Babcock	Techno-economic analysis	SWC/UoS	*Techno-Economic Analysis of Decentralised Sustainable Energy Systems Installation and Market Potential at the Sector and System Level* 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 is the selection of the most optimal range of technologies that satisfies the trilemma of best economics, best environmental performance, and best social benefits. 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.
Booth Welsh	Industry 4.0	UoS	*Industry 4.0 and Augmenting the Millennial Worker* This research project focuses on utilising Industry 4.0 technologies and augmenting the millennial worker within the renewable energy sector. By developing augmented reality technology there is the potential to bring vital information and data available at point-of-use to the board room or office.

Appendix XII – Renewable Engine Development Grants Awarded

The project partnership outlined that the development grants helped further develop the research possibilities. The development grants were awarded in 2 stages, with 5 industry partners receiving grant support of €345,786.30, towards total eligible costs of €486,278.20. An overview of the development grants awarded is provided in the table below.

Overview of RE Development Grants Awarded					
Company	**Project area**	**Institution**	**About the Development Grant**	**Approved Total Eligible Costs**	**Grant Amount Awarded**
Platinum Tanks	Rotomoulding composites	QUB	**Project Title:** Development of Hybrid Rotomoulded Composite Structures for Solar Panels **Project Description:** The project will involve the combination of new generation thermoplastic composite materials with the traditional process of rotational moulding to manufacture structural parts such as frames for solar panels. This is an application in which mechanical and thermal performance are critical design requirements.	€90,683.71	€72,546.97
Organic Power	Small anaerobic digesters	ITS	**Project Title:** Small Scale Off-Grid Renewable Power **Project Description:** The benefits of AD to convert wastes to energy are well recognised, but traditional large scale systems which have a relatively high fixed cost has limited their wider use. OP wishes to develop and market an 'off-grid', robust, modular, cost effective small-scale anaerobic digestion (SSAD) system (circa 20 Kw+/hour). This system will convert organic matter into biogas, and makes the technology suitable for a variety of applications particularly where 'off-grid' power and waste management would be of considerable benefit. The system will be mobile, fit inside two 40ft containers, and provide "plug and play" functionality. The SSAD will: • Bring benefits of AD to a section of the marketplace currently not catered for • Provide off-grid energy generation (electricity and heat). • Upgrade and provide a nutrient rich fertiliser from the digester effluents. • Aid pathogenic loads reduction • Reduce local odour and greenhouse gas emissions.	€114,360.47	€91,488.38
Soltropy	Solar collectors	UoS	**Project Title:** Incorporating heat storage inside twin-walled evacuated tube solar collector. **Project Description:** We propose to incorporate thermal storage inside twin-walled evacuated tube solar collectors. This increases the system efficiency, allows oversizing and so contribute to space heating without increasing the hot water cylinder size and be used to preheat 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 a high specific heat capacity. The challenge is to find a material that is affordable, safe and is compatible with all	€74,407.02	€56,677.62

Overview of RE Development Grants Awarded					
Company	**Project area**	**Institution**	**About the Development Grant**	**Approved Total Eligible Costs**	**Grant Amount Awarded**
			materials that it is in contact with.		
Kingspan Water & Energy	Lightweight rotomouled structures	QUB	**Project Title:** Development of lightweight rotomouled structures for off-shore energy generation. **Project Description:** The development of advanced manufacturing processes for large, low cost and lightweight structural components is essential to the future success of the marine energy generation sector. 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.	€140,727.00	€72,198.00
B9	Compressed air energy storage	SWC/QUB	**Project Title:** Liquid piston-immersed heat exchanger tests **Project Description:** Near isothermal compressed air energy storage is an emerging technology for enabling better utilisation of intermittent sources of renewable energy such as wind and solar PV that are increasingly being curtailed in the Interreg area. This project seeks to develop additional understanding of immersed heat exchanger performance of the compressed air system that has been developed by B9 when tested within a liquid piston test rig, so that a more optimised design solution can be established. The scope involves iterative testing of a range of heat exchange elements sequentially fitted within the test cylinder, each with a different surface area and geometric configuration, and each operated through a range of piston velocities / liquid flow rates.	€66,100.00	€52,875.33

Appendix XIII – Renewable Engine Development Grant Project Report Findings

Company / Project	Key Findings/ Conclusions from end of project report
B9 - Experimental Analysis of Efficiency Enhancement in a Liquid Piston Gas Compressor Using Metal Foam and 3D Printed Inserts	The results of this project to analyse the efficiency enhancement in a liquid piston gas compressor for CAES application have been encouraging with metal foam heat exchange inserts providing the best overall performance. More research using mathematical modelling and physical testing would be needed to arrive at the optimum solution for a prototype specification. B9 Energy has moved its focus to electrolysis as a preferred longer duration energy storage vector to support intermittent renewable generation which involves compression and expansion of several gases including hydrogen and oxygen but also derivatives such as ammonia and di-methyl ether for example. B9 Energy noticed the growing trend towards using liquid pistons for hydrogen compression and will endeavour to assess the potential for using heat exchange inserts to improve compression efficiency to near isothermal conditions.
Kingspan - Hydrogen Storage Vessel Development	Whilst the trial results did not provide any clear and tangible benefits between the moulding processes at this time, it made clear the additional processing capabilities available in the future with the electrically heated mould. With the ability to pressurise and perform polymer additions safely and in a controlled manner the AMS system certainly has merits. However, what has been made clear is that for short time frame developments a conventional mould for a simple geometric design can provide the same manufacturing capabilities. Kingspan will continue to trial the AMS system to optimise the moulding process to provide a liner ready for production. Throughout the Renewable Engine project Kingspan completed a commercialisation study to complement the research and development undertaken on the Type IV tank. As such, Kingspan developed an internal strategy on Hydrogen Innovation that will provide them with a route to market. Kingspan is committed to being a world leader in the Hydrogen storage space.
Organic Power - Small scale anaerobic digester (SSAD)	The project report noted the following: 1. AD Slurry only prototype (SOP) - Fully completed 2. Feedstock Intake system (FIS) - Fully completed with qualification. 3. Pre -Treatment Tech (PTT) - Fully completed with qualification. 4. Energy Storage System (ESS) - Not Completed as this task was dropped as during the project there had been such advancement in 'energy storage', and it was already proven to work with AD systems there was nothing to be gained by us repeating such a task. This was explained and agreed in a modification which also had the benefit of saving costs. 5. Process Control Design (PCD) - Fully completed. 6. Optimise Plant Operation (OPO) - Partially completed. 7. Project Branding and Identity (PBI) - Fully Completed and qualified under. The engagement with PFP (Power from Plastic - another company) and Invest NI was extremely significant, such that IrBea (Irish Biogas Association) became involved. All of this activity came about as a direct result of the RE supported project and for this reason Organic Power concluded that in spite of the limitations faced the RE project had been a resounding success. IrBea's interest and direct involvement led to the SSAD being installed at Gurteen Agricultural College in the Republic of Ireland where Organic Power have agreed to continue further testing and development of the unit with the intention of commercial development as soon as feasible.

Company / Project	Key Findings/ Conclusions from end of project report
Platinum Tanks Ltd - Rotomoulding composites	The aim of the project was 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 frames for solar panels. The combination of a new range of thermoplastic composites in a part that was traditionally produced using rotational moulding is a step change in the manufacturing process for structural parts. The outcome of the project will allow Platinum Tanks to begin manufacture of a new range of lightweight products such as solar panel frames for the renewable energy market. Rotomoulded Solar Panel Frame - The result of the project is a stable base capable of carrying two 320W solar panels which does not require any additional infrastructure to install. The product can be moved to where it is required using pallet forks and the hollow body can be filled with water to give additional stability in locations where there is concern about high winds. There is an inbuilt compartment capable of storing batteries and power management equipment. Multiple frames could be linked using the MC4 branch connectors to create a portable array of panels with enough capacity for any potential application.
Soltrophy - Solar Collectors	The prototype phase change material storage tubes show a promising solution. The amount of energy stored in the erythritol filled copper containment tubes is calculated by adding the sensible heat storage when solid, the latent heat of fusion when it is melting and the sensible heat storage when liquid. This amounts to around 1.8 times the storage capability of water in the same volume and means around 4.2 litres water equivalent in the volume of the evacuated tube as compared with water at 2.3 litres. There are challenges however with how long the energy can be stored and currently would only be suitable for diurnal storage with energy stored during the day being used in the evening. At night the energy leaks away from the manifold header so that by the following morning the energy is greatly reduced. This, however, is still a useful solution with energy harvested during the day being utilised in the evening for space and water heating and would a good initial market to exploit. A typical house roof would be able to accommodate around 180 evacuated tubes with an equivalent of around 720 litres of water storage. The long term durability of the system has not been ascertained nor the long term stability of the phase change material itself but this is currently ongoing. Further work would also include safety aspects regarding flammability of the erythritol and the load on the roof itself as well as the aforementioned Insulation properties of the manifold header being improved.

Appendix XIV – SPIRE 2 Publications

No.	Cross-Border Authorship	Title	Authors
1	Yes	Economic Assessment of High Renewable Energy Penetration Scenario in 2030 on the Interconnected Irish Power System	Shurui Wang Co-Authors: Ye Huang; Inna Vorushyro; Haisheng Chen; Dominic McLarnon; Paul MacArtain; Neil Hewitt
2	Yes	High Temperature Air Source Heat Pump Coupled with Thermal Energy Storage: Comparative Performances and Retrofit Analysis	Khoa Xuan Le, Ming Jun Huang, Nikhilkumar Shah, Christophe Wilson, Paul MacArtain, Raymond Byrne, Neil J Hewitt
3	Yes	Efficient energy storage technologies for photovoltaic systems	Hoda Akbari, Maria C. Browne, Anita Ortega, Min Jun Huang, Neil J Hewitt, Brian Norton, Sarah J. McCormack
4	Yes	Techno-economic assessment of cascade air-to-water heat pump retrofitted into residential buildings using experimentally validated simulations	Khoa Xuan Le, Ming Jun Huang, Nikhilkumar N.Shah, Christopher Wilson, Paul MacArtain, Raymond Byrne, Neil J. Hewitt
5	Yes	Techno-economic Modelling of Large-Scale Compressed Air Energy Storage Systems	Y.Huang H.S.Chen X.J.Zhang P.Keatley M.J.Huang I.Vorushylo Y.D.Wang N.J.Hewitt
6	Yes	Technique for Pre-Compliance Testing of Phasor Measurement Units.	Brogan, P.V.., Laverty, D.M., Zhao, X., Hastings, J., Morrow, D.J., (all QUB) Vanfretti, L. (Rensselaer Polytechnic Institute, Troy, NY, USA).
7	Yes	Observed site obstacle impacts on the energy performance of a large scale urban wind turbine using an electrical energy rose	Raymond Byrne and Neil J. Hewitt and Philip Griffiths and Paul MacArtain
8	Yes	Integration of compressed air energy storage with wind generation into the electricity grid	Y Huang and A Rolfe and I Vorushylo and P Keatley and R Byrne and P MacArtain and D Flynn and N Hewitt
9	Yes	Increased Benefit Of ZnBr Flow Battery With 33kWp PV System And Smart Tariff Structure	Paul MacArtain and Raymond Byrne and Neil J Hewitt
10	Yes	Electricity autoproduction, storage and billing: A case study at Dundalk Institute of Technology, Ireland	Conall E.Ruth Raymond Byrne Neil J. Hewitt Paul MacArtain
11	Yes	An assessment of the mesoscale to microscale influences on wind turbine energy performance at a peri-urban coastal location from the Irish wind atlas and onsite LiDAR measurements	Raymond Byrne and Neil J. Hewitt and Philip Griffiths and Paul MacArtain
12	Yes	A comparison of obstacle and surface roughness models in predicting the performance of an 850 kW wind autoproducer with onsite LiDAR measurements in a peri-urban area	Raymond Byrne and Neil J. Hewitt and Philip Griffiths and Paul MacArtain
13	Yes	IEA Wind TCP - Task 27, Recommended Practice 19: Micro-Siting Small Wing Turbines for Highly Turbulent Sites	Raymond Byrne & 14 other international authors
14	Yes	IEA Wind TCP - Task 27, Small Wind Technical Report	
15	Yes	Energy Storage, Rural Solutions and Community Acceptance	Gerard Reaburn and Paul MacArtain and Raymond Byrne and Neil J. Hewitt
16	Yes	The Energy Ambassadors. A gamified, interactive, energy information programme for communities.	
17	Yes	Assessment for a typical season of energy consumption, of auto-production from wind, and suitable energy storage for onsite potato storage, in Ireland.	
18	Yes	A Study of Wind Turbine Performance Decline with Age through Operation Data	Byrne, R.; Astolfi, D.; Castellani, F.; Hewitt, N.J.
19	Yes	Analysis of Wind Turbine Aging through Operation Curves.	Astolfi, D.; Byrne, R.; Castellani, F.
20	Yes	Estimation of the Performance Aging of the Vestas V52 Wind Turbine through Comparative Test Case Analysis.	
21	Yes	Measured wind and morphological characteristics of a peri-urban environment and their impact on the performance of an operational large-scale wind turbine	Raymond Byrne and Neil J. Hewitt and Philip Griffiths and Paul MacArtain
22	Yes	Cost-benefit analysis of storage devices for provision of multiple services in MV distribution networks	Arijit Bagchi, Robert Best, D. John Morrow (all QUB), Andrew Cupples (NIE Networks), Jonathan Pollock (ESB Networks), Ian Bailie (NIE Networks)
23	Yes	Battery Energy Storage Systems Allocation Considering Distribution Network Congestion	Ahmed A. Raouf Mohamed, D John Morrow, Robert Best, Ian Bailie, Andrew Cupples, Jonathan Pollock

No.	Cross-Border Authorship	Title	Authors
24	Yes	Experimental Study of the Heat Pump with Variable Speed Compressor for Domestic Heat Load Applications	Muhammad Abid, Neil Hewitt, Ming Jun Huang, Christopher Wilson Donal Cotter
25	Yes	Variable Speed Heat Pump Compressor for Demand Side Management and Network Stability	Muhammad Abid, Neil Hewitt, Ming Jun Huang
26	Yes	Heat Supply Temperature Impact on the Seasonal Cost of Low Carbon Domestic Heat Pump Technology	Muhammad Abid, Neil Hewitt, Ming Jun Huang, Christopher Wilson Donal Cotter
27	Yes	Impact of Heating Capacity Modulation and Heat Supply Temperature Impact on the Performance of Variable Speed Compressor based Developed Domestic Heat Pump	
28	Yes	Reducing Demand for Energy with Variable Speed Compressor & Heat Supply Temperature for the Developed Domestic Air Source Heat Pump System	
29	Yes	The Role of Domestic Integrated Battery Energy Storage Systems for Electricity Network Performance Enhancement	Corentin Jankowiak, Aggelos Zacharopoulos, Caterina Brandoni, Patrick Keatley, Paul MacArtain, Neil Hewitt
30	Yes	Assessing the benefits of decentralised residential batteries for load peak shaving	
31	Yes	Economic Assessment of High Renewable Energy Penetration Scenario in 2030 on the Interconnected Irish Power System	Shurui Wang; Ye Huang; Inna Vorushyro; Haisheng Chen; Dominic McLarnon; Paul MacArtain; Neil Hewitt
32	Yes	Benefits of interconnection in the 2030 Integrated Single Electricity Market (I-SEM) with high renewable generation	
33	Yes	Progress in electrical energy storage system (ESS) economics: a critical review	Shurui Wang; Ye Huang; Yujie Xu; Inna Vorushylo; Xinjing Zhang; Neil Hewitt; Haisheng Chen
34	Yes	Universities as a source of grid flexibility: A case study	Bani Mustafa, M., Keatley, P., Huang, Y., Agbonaye, O., Vorushylo, I. & Hewitt, N.
35	Yes	Evaluation of a battery energy storage system in hospitals for arbitrage and ancillary services	
36	Yes	A comparison of four microscale wind flow models in predicting the real-world performance of a large-scale peri-urban wind turbine, using onsite LiDAR wind measurements	Raymond Byrne, Neil J. Hewitt, Philip Griffiths, Paul MacArtain
37	Yes	A new micro-siting approach for large-scale wind turbines at industrial sites	Raymond Byrne, Paul MacArtain, Neil J. Hewitt
38	Yes	Techno-Economic Assessment of Grid-Level Battery Energy Storage Supporting Distributed Photovoltaic Power	Javier Lopez-Lorente, Xueqin Amy Liu, Robert J. Best, George Makrides, D John Morrow
39	Yes	Modelling erosion-corrosion in metals: the effects of elastic rebound and impact angle on erosion-corrosion maps	Stack, M. M. & Jana, B. D
40		A state of the art techno-economic review of distributed and embedded energy storage	Neil McIlwaine, Aoife Foley, Dlzar Al Kez, D John Morrow
41		System service provision capabilities of storage devices connected to a MV distribution network: A Northern Ireland case study	Bagchi, A., Best, R., Morrow, D. J. (all QUB) , Pollock, J., Bailie, I. & Cupples, A. (all NIE Networks)
42		Voltage control in LV distribution networks considering increasing penetration of low carbon technologies	Arijit Bagchi, Declan Bradley, Robert Best, D. John Morrow (all QUB)
43		The Deployment of Low Carbon Technologies in Modern Distribution Networks	Ahmed A.Raouf Mohamed, D. John Morrow, Robert Best
44		Maximizing the Profits of Battery Energy Storage Systems in the Integrated Single Electricity Market	
45		Real-Time Model Predictive Control of Battery Energy Storage Active and Reactive Power to Support the Distribution Network Operation	
46		Domestic Battery Power Management Strategies to Maximize the Profitability and Support the Network	Ahmed A.Raouf Mohamed, Robert J. Best, Xueqin Liu, and D. John Morrow
47		Analysis on field trial of high temperature heat pump integrated with thermal energy storage in domestic retrofit installation	Nikhilkumar N. Shah, Christopher Wilson, Ming J. Huang, Neil J. Hewitt
48		How heat pumps and thermal energy storage can be used to manage wind power: A study of Ireland.	Inna Vorushylo, Patrick Keatley, Nikhilkumar Shah, Richard Green, Neil Hewitt
49		Some thoughts on mapping tribological issues of wind turbine blades due to effects of onshore and offshore raindrop erosion	Kieran Pugh, Ghulam Rasool, Margret M Stack

No.	Cross-Border Authorship	Title	Authors
50		Some views on the mapping of erosion of coated composites in tidal turbine simulated conditions	G. Rasool and Margaret M Stack
51		Raindrop Erosion of Composite Materials: Some Views on the Effect of Bending Stress on Erosion Mechanisms.	Kieran Pugh, Margret M Stack, Ghulam Rasool
52		Effect of BESS Response on Frequency and RoCoF During Under Frequency Transients.	Brogan, P.V., Best, R., Morrow, J. (all QUB), McKinley, K. and Kubik, M.L (both AES).
53		Energy storage allocation in power networks – A state-of-the-art review.	Lopez Lorente. J., Liu, X., Best, R., Morrow, D.J. (all QUB)
54		Reactive power injection from battery energy storage during voltage dips at a thermal power plant	Best, R., Alikhanzadeh, A., Brogan, P., Morrow, D.J. (all QUB), Kubik, M., Mongan, B. (both AES).
55		Per Unit Displacement of Synchronous Inertia with BESS Synthetic Inertia Devices.	Brogan, P.V., Best, R., Morrow, D.J., Alikhanzadeh, A. (all QUB), Kubik, M. (AES).
56		Triggering BESS Inertial Response with Synchronous Machine Measurements.	Brogan, P.V., Best, R., Morrow, D.J., Bradley, C., Rafferty, M. (all QUB), Kubik, M. (AES).
57		Universities as a source of grid flexibility: A case study	M Bani
58		Overview of findings from a small wind field trial in Ireland	Raymond Byrne
59		Potential for Crowdsourced Weather Stations to Assess Intra-Hourly Variability of Photovoltaic Systems	Javier Lopez Lorente, Xueqin (Amy) Liu, John Morrow, Paul Brogan
60		Effect in the aggregated demand of solar-plus-storage prosumers in the residential sector	
61		Spatial Aggregation of Small-scale Photovoltaic Generation Using Voronoi Decomposition	
62		Worldwide evaluation and correction of irradiance measurements from personal weather stations under all-sky conditions	
63		Residential Battery Energy Storage Sizing and Profitability in the Presence of PV and EV	Ahmed A.Raouf Mohamed, Robert J. Best, Xueqin Liu, and D. John Morrow
64		Design, Valuation and Comparison of Demand Response Strategies for Congestion Management	Agbonaye, O., Keatley, P., Huang, Y., Bani Mustafa, M., & Hewitt, N.
65		Value of Demand Flexibility for providing Ancillary Services: A case for Social Housing in the Irish DS3 market.	Agbonaye O., Keatley P., Huang Y., Bani-Mustafa M., Ademulegun O., Hewitt N.
66		Value of Demand Flexibility for Providing Ancillary Services: A Study of The Irish DS3 Market.	
67		Mapping Demand Flexibility: A Spatio-temporal Assessment of Flexibility Needs, Opportunities and Response Potential	Agbonaye O., Keatley P., Huang Y., Ademulegun O., Hewitt N.
68		Phase Angle Difference Analysis Using PMU Data on grids with Varying Wind Penetration	Connor Duggan, Xueqin Liu, Paul Brogan, John Morrow
69		Psuedo-Realtime PMU Event Detection Framework	Connor Duggan, Paul Brogan, Xueqin Liu, David Laverty, John Morrow
70		MQTT Architecture for Stream Analytics of PMU Data	Paul Brogan, Andres Jarmillo Moreno, Xueqin Amy Liu, John Hastings, David Laverty, D. John Morrow, Connor Duggan, Robert Best
71		Representing Synchrophasor Data Using JSON	
72		Synchronisation Control Action for Very Low-Frequency Oscillations	Connor Duggan, Paul Brogan, Xueqin Liu, Robert Best, John Morrow
73		Single electricity market forecasting and energy arbitrage maximization framework	Ahmed A.Raouf Mohamed, Robert J. Best, Xueqin Liu, and D. John Morrow
74		A Comprehensive Robust Techno-Economic Analysis and Sizing Tool for the Small-Scale PV and BESS'	
75		Impact of the deployment of solar photovoltaic and electrical vehicle on the low voltage unbalanced networks and the role of battery energy storage systems	Ahmed A.Raouf Mohamed, Robert J. Best, D. John Morrow, Andrew Cupples, and Ian Bailie
76		Understanding the impact of high penetration residential batteries with low carbon technologies on the low voltage networks'	Ahmed A.Raouf Mohamed, Robert J. Best, Xueqin Liu, and D. John Morrow

No.	Cross-Border Authorship	Title	Authors
77		Domestic Battery Power Management Strategies to Maximize the Profitability and Support the Network	
78		Residential Battery Energy Storage Sizing and Profitability in the Presence of PV and EV	
79		Distributed battery energy storage systems operation framework for grid power levelling in the distribution networks	Ahmed A.Raouf Mohamed, D. John Morrow, Robert Best, Andrew Cupples, Ian Bailie, and Jonathan Pollock
80		Real-Time Model Predictive Control of Battery Energy Storage Active and Reactive Power to Support the Distribution Network Operation	Ahmed A.Raouf Mohamed, D John Morrow, Robert Best
81		Maximizing the Profits of Battery Energy Storage Systems in the Integrated Single Electricity Market	
82		A state-of-the-art techno-economic review of distributed and embedded energy storage for energy systems	Neil McIlwaine, Aoife Foley, Dlzar Al Kez, D John Morrow
83		Modelling the effect of distributed battery energy storage in an isolated power system	Neil Mcilwaine, Aoife M. Foley, Robert J. Best, Dlzar Al Kez
84		Stacking Battery Energy Storage Revenues in Future Distribution Networks	Ahmed A.Raouf Mohamed, Robert Best, Xueqin Liu, D John Morrow, Andrew Cupples, Jonathan Pollock
85		Erosion mapping of through-thickness toughened powder epoxy gradient glass-fiber-reinforced polymer (GFRP) plates for tidal turbine blades	Hassan, E., Zekos, I., Jannson, P., Pecor, T., Floreani, C., Robert, C., Ó Brádaigh, C. M. & Stack, M. M.
86		Mapping of meteorological observations over the island of Ireland to enhance the understanding and prediction of rain erosion in wind turbine blades	Nash, J. W. K., Zekos, I. & Stack, M. M., 28 Jul 2021, In: Energies. 14, 15, 34 p., 4555.
87		Rain erosion maps for wind turbines based on geographical locations: a case study in Ireland and Britain	Pugh, K. & Stack, M
88		Developing a framework for a retail electricity model incorporating energy storage	Neil McIlwaine, Aoife M. Foley, D. John Morrow, Dlzar Al Kez, Chongyu Zhang, Xi Lu, Robert J. Best

Appendix XV – SPIRE 2 PhD Projects and PhD Progress

Institute	PhD Project Title	PhD Status (as of June 2022)
DkIT	'Energy and Storage, Rural Solutions and Community Acceptance'.	Completed
QUB	'Oscillation Location and Mitigation Using Energy Storage'.	Ongoing
QUB	'A market analysis of customer connected mass energy storage.'	Submitted
QUB	'Integration of Distributed Small-Scale Photovoltaic and Energy Storage Systems in Power Networks.'	Completed
QUB	'The Integration of Battery Energy Storage Systems in Modern Distribution Networks'	Completed
Strathclyde	"Numerical analysis of high velocity raindrop impact on wind turbine blades"	Completed
Strathclyde	"Modelling Hail Impact on Wind Turbine Blades".	Ongoing
Strathclyde	"Erosion Issues in Tidal Turbine Blades"	Ongoing
Strathclyde	'The Development of Testing Standards for the Rain Erosion of Wind Turbine Blades'	Completed
Strathclyde	'An Investigation into The Damaging Effects of Rain Erosion on Wind Turbine Blades in Various Environmental Conditions"	Completed
UU	'Assessing Demand Flexibility as a new Business Model for Decarbonizing Social Housing'	Completed
UU	'Optimal Integrated Energy Storage solutions for the Electrification of Heat and Transport at a Domestic Level'.	Completed
UU	'Battery Energy Storage Systems in Hospitals for Flexibility, Resilience and Arbitrage'	Submitted
UU	''Phase change and alternative materials for domestic thermal energy storage"	Submitted
UU	'I-SEM, GB and French electricity market modelling.'	Completed
UU	'Variable Speed Heat Pump Compressors for Demand Side Response & Network Stability'	Completed

Appendix XVI – Bryden Centre PhD Projects

Institution of PhD Student	Project Title	Project Summary
AFBI	Nutrient Management of digestate combined with energy recovery	In NI, 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.
AFBI	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).
LyIT	Modelling the dynamic responses of floating photovoltaic solar arrays to develop the basis for 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.
LyIT	Transitioning towards social acceptability of MRE in Ireland	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).

Institution of PhD Student	Project Title	Project Summary
		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	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.
LyIT	Experimental and numerical simulations of a horizontal cross flow turbine	The role of mooring system of ORE devices is to keep the devices on station for the entire life time while maintaining mooring tensions are within acceptable limits. Mooring lines fatigue and failure are the most critical point of a 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 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 optimal design: 1) The non-linear behaviour of new materials (synthetic ropes, the Exeter Tether, etc.) 2) The non-linear hydrodynamics 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 aforementioned non-linearities in dynamic analysis of design due to 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 optimal design of mooring system.
LyIT	Decision support tool for optimal sequencing of	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

Institution of PhD Student	Project Title	Project Summary
	installation operations for an offshore wind farm	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	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.
UU	Performance Study and Validation of the Downdraft Biomass Gasification	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. *Assessment* - techno-economic and environmental assessment of the full bioenergy production chain
QUB	Lithium ion battery degradation study using spectroscopic techniques	<u>Project Aims</u> • Improving the lifetime of lithium-based batteries • Investigate and understand degradation mechanisms • Apply to stationery 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. <u>The Challenges Facing Battery Technology in the Industry</u> 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.

Institution of PhD Student	Project Title	Project Summary
		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	Animal use of high-flow tidal environments and the potential for spatial and temporal overlap with marine renewable energy devices	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 heterogenous 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.
QUB	Optimal integration of joint energy and power services to determine true strike price of offshore wind	<u>Industry Problems / Challenges:</u> 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	Waste Heat Recovery from Refrigeration Cycles	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

Institution of PhD Student	Project Title	Project Summary
QUB	Distributed Solid Oxide Fuel Cell (SOFC) power and heat supply equipment	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	Hydrogen generation via gasification / reforming of bio-carbon produced from dedicated energy crops.	The Biorefinery (or Anaerobic Biorefinery) has been receiving increasing attention in recent years, and is based on a holistic approach to feedstock's, processing technologies and products which seeks to add value and maximise synergies between material and energy flows. With the proposed development of both Anaerobic Digestion and Gasification facilities within the Belfast Harbour area, a unique opportunity has arisen to combine the Biorefinery concept with Life Cycle based modelling, based on operational facilities. LCA modelling will be used to identify synergies between feedstock's and processes/technologies and optimal/added value utilisation scenarios, including:se of digestate from the AD process as a feedstock for gasification, Upgrading and blending of biomethane and syngas to produce Hythane, Biomethane and/or hythane substituting for diesel in Belfast City Council Refuse Collection Vehicles (RCV's), Translink Buses; and Heavy Fuel Oil in Cruise Ships or Ferries. The LCA will enable the full range of environmental impacts to be evaluated, including climate change and impacts on human health in Belfast in Disability Adjusted Life Years (DALYs). A further added-value of the project will be the development of an outline design of a City-wide decision support tool, combining life-cycle analysis with Data Analytics.
QUB	Ensuring Biofuels Meet Future Emissions Standards	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	Adding Value to Waste Glycerol 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

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		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.
QUB	Extraction of biofuels from lignocellulosic biomass through anaerobic digestion (Valorisation of biomass)	In Northern Ireland alone there is an estimated annual generation of 150,000 tonnes of solid lignocellulosic digestate as a by-product 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	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	Fatigue Assessment 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	Thermochemical Conversion of Biomass Lignin into	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

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	Mesoporous Carbon Materials	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.
UHI	Optimisation of data for use in planning marine energy 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	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.
UHI	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

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UHI	Multidisciplinary Design Optimisation method for application to automotives	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	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	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.
UHI	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

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		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	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	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.
UHI	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.

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		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.