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Northern Ireland
Science Industry Panel

Engineering Biology Research in Northern Ireland

A Strategic
Roadmapping
Study

Full Report

April 2026

Delivered by

IfM Engage

**Stakeholders Engaged
from Organisations**

- Agri-Food and Biosciences Institute (AFBI)
- Animal Health and Welfare Northern Ireland (AHWNI)
- Almac Group
- Advanced Manufacturing Innovation Centre (AMIC) Belfast
- Catalyst
- Causeway Sensors
- Department of Agriculture, Environment and Rural Affairs (DAERA)
- Department for the Economy (DfE) / Matrix
- Department of Business and Trade Northern Ireland
- Department of Science, Innovation and Technology (DSIT)
- Invest Northern Ireland (Invest NI)
- Northern Ireland Antimicrobial Resistance (NI AMR) Network
- Navico Group
- Peter Simpson Consulting
- Queen's University Belfast (QUB)
- The Executive Office of Northern Ireland
- Ulster University

**IfM Engage
Project Team**

- Arsalan Ghani
- Jonathan Hughes
- Rob Phaal
- Imoh Ilevbare

**DfE /
Matrix Team**

- Sam Turner
- Simon Grattan
- Matrix Secretariat

This report has been prepared by the project delivery team at IfM Engage on behalf of Matrix, the Northern Ireland Science Industry Panel, for the Department for the Economy.

Executive Summary

This report presents the findings and recommendations of a strategic roadmapping study into engineering biology opportunities for Northern Ireland, commissioned by Matrix, the Northern Ireland Science Industry Panel, on behalf of the Department for the Economy. The study was delivered by IfM Engage at the University of Cambridge, applying the Cambridge strategic roadmapping methodology integrated with the UK Government Futures Toolkit.

Engineering biology—the design, scaling, and commercialisation of biology-derived products and services—has been identified by the UK Government as one of five critical technologies for the nation’s future, backed by £2 billion of public investment over the next decade. Globally, the field could generate up to \$4 trillion per year in economic impact by 2030–2040. This study examined Northern Ireland’s position across four priority sectors: Healthcare and Medicine, Agri-Food and Environment, Industrial Biotechnology, and Environmental Solutions.

Study Approach

The research drew on a review of over 200 sources and international benchmarking against seven comparator jurisdictions; ten semi-structured interviews with senior figures across academia, industry, and government; a sixteen-respondent stakeholder survey; and a strategic roadmapping workshop in Belfast on 3 February 2026 attended by 35 participants. Over 1,200 individual statements were synthesised into 79 thematic clusters across three analytical layers: *Why* (drivers and trends), *What* (applications and opportunities), and *How* (resources and enablers).

Northern Ireland’s Key Strengths

The study identified a credible foundation for engineering biology development. Northern Ireland possesses internationally recognised research across Queen’s University Belfast, Ulster University, and the Agri-Food and Biosciences Institute (AFBI). Anchor companies present in Northern Ireland, including Randox Laboratories and Norbrook Laboratories, among others, provide global industrial reach. The region’s precision medicine and diagnostics cluster is an established competitive strength. Unique dual market access under the Windsor Framework enables products to satisfy both UK (MHRA) and EU regulatory requirements simultaneously. Significant new infrastructure investments through City and Growth Deals—including the Future Medicines Institute, AMIC, and iReach—create industry-facing platforms. The agri-food sector, the largest in the UK as a proportion of regional GDP, provides a substantial demand base for engineering biology applications.

Key Challenges

The above stated strengths are constrained by systemic barriers. Northern Ireland lacks a life sciences Catapult or equivalent scale-up facility, and has lost domestic manufacturing capability for essential reagents. A persistent ‘valley of death’ exists between academic research (TRL 1–3) and commercial application (TRL 6+). Skills gaps—consistently the most cited barrier—span biomolecular discovery, synthetic biology, biomanufacturing, regulatory expertise, and entrepreneurial training. Brain drain to the Republic of Ireland and Great Britain impacts the talent base. Fragmented governance, with no cross-departmental coordination mechanism, compounds these challenges. Northern Ireland receives approximately 1% of total UKRI funding despite comprising 2.8% of the UK population, and none of the six national engineering biology mission hubs are led from the region.

Priority Initiatives

Six priority topic roadmaps were developed through the workshop, scored by participants for opportunity and feasibility (1–5 scale):

Initiative	Opp.	Feas.	Key Implication
Food Security & Resilience	5	3	Highest opportunity; TRL 3–4 gap and cluster mapping needed
Scale-Up Capabilities	5	3	Known customer pull; infrastructure investment required
Circular Bioeconomy	4	3	Lough Neagh as flagship demonstrator opportunity
Agri-Tech Innovation	4	2	Lowest feasibility due to agricultural data access barriers
Diagnostics & Biosensors	4	4	Strongest combined score; most immediately actionable
One Health	3	3	Strategically important; requires cross-sector steering group

Recommendations

The study's recommendations are organised across three interconnected dimensions:

- Policy Recommendations:** Establish a cross-departmental Engineering Biology Coordination Body with representation from DfE, DAERA, DoH, Invest NI, universities, AFBI, and industry. Develop a proactive Windsor Framework regulatory strategy maximising dual market access. Create a comprehensive workforce strategy spanning doctoral training to apprenticeships. Commission an integrated data strategy addressing farm-level, health, and environmental data access. Launch a sustained public engagement programme using compelling local case studies.
- Investment Priorities:** Invest in shared engineering biology infrastructure ('research hotel' model) with fermentation capacity, flexible laboratory space, and formal Catapult network linkages. Establish a dedicated TRL 3–4 bridging fund to address the valley of death across sectors. Launch a bespoke diagnostics and biosensors accelerator programme. Fund a Lough Neagh circular bioeconomy demonstrator as a flagship project. Adopt a coordinated approach to accessing UKRI ring-fenced engineering biology funding and Horizon Europe opportunities.
- Future Research Opportunities:** Feasibility study for Northern Ireland as a cell therapy clinical trial hub. Agricultural microbiome engineering programme building on AFBI's capabilities. Bio-based packaging R&D linking agricultural waste to biopolymer production. Digital twins and AI for bioprocess optimisation. Integrated One Health surveillance platform. Comprehensive all-island engineering biology capability mapping. Disruptive impact assessment of threats to existing NI industries.

The current moment represents a window of opportunity. UKRI is ring-fencing significant engineering biology funding, the global bioeconomy is expanding rapidly, and Northern Ireland's unique Windsor Framework position creates advantages no other UK region can replicate. The six topic roadmaps should be pursued as an integrated portfolio—siloed implementation would negate the synergies that make engineering biology transformative. Northern Ireland's small scale, often perceived as a limitation, becomes a genuine advantage when leveraged strategically: comprehensive coordination, living laboratory testing, and niche reputation-building are all feasible in ways that larger regions cannot replicate.

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Foreword

Professor Sam Turner

Chair of the Study

Engineering biology has moved decisively from the margins of scientific research to the centre of economic, environmental and health policy. As this report demonstrates, it is now a foundational technology with the potential to reshape food systems, healthcare, manufacturing and environmental stewardship. For Northern Ireland, the question is no longer whether engineering biology matters, but how deliberately and effectively we choose to engage with it.

This study provides a clear, evidence-based assessment of Northern Ireland's position. It shows that the region has genuine strengths: internationally recognised research excellence, established industry anchors, a strong agri-food base, and unique dual market access under the Windsor Framework. At the same time, it is candid about the barriers that constrain progress—most notably fragmented coordination, skills shortages, limited scale-up infrastructure, and a persistent gap between research and commercial deployment.

A central message from the work is the importance of focus. Northern Ireland cannot and should not attempt to compete across the full breadth of engineering biology. Instead, the opportunity lies in building depth in a small number of areas where existing capability, market demand and societal need align most strongly. The six priority initiatives identified in this report should be treated as an integrated portfolio, not a set of disconnected options.

The study also highlights a narrow but important window of opportunity. Significant UK-wide investment is now being directed towards engineering biology, global bioeconomy markets are expanding rapidly, and Northern Ireland's scale offers advantages as a living laboratory that larger regions cannot replicate. Capturing these benefits will require coordinated leadership, sustained investment, and a willingness to act on the evidence set out here.

I would like to thank the many contributors from industry, academia, government and the wider ecosystem who gave their time and insight. Their collective input has ensured that this report is both ambitious and grounded in reality. My hope is that it serves not simply as an analysis of opportunity, but as a practical foundation for decisive action to position Northern Ireland as a credible, focused and competitive participant in the engineering biology economy.

Steering Group Members

Name	Role
Prof. Sam Turner (Chair)	Chief Executive Officer, Advanced Manufacturing Innovation Centre, Belfast
Dr. Simon Grattan	Director of Research Services & Government Affairs, Almac Group
Prof. Richard Kennedy	Medical Director and Global VP of Biomarker Development, Almac Diagnostic Services
Dr. Peter B. Simpson	CEO Peter Simpson Consulting Ltd
Carmel McConville	Economist, DfE
Prof. Helen McCarthy	Chief Scientific and Technology Adviser, The Executive Office NI
Prof. Denise Fitzgerald	Professor of Neuroimmunology, QUB
Prof. Nigel Scollan	School of Biological Sciences and Institute for Global Food Security, QUB
Prof. Tara Moore	Professor of Personalised Medicine, Ulster University
Elaine Groom	NICP Horizon Europe, AFBI
Johnathan Dalzell	Deputy Director, Science Engagement & Science Advice, CSTA Office, DAERA
Masoud Shirali	Head of Farm Animal Bioinformation, AFBI
Dr. Sam Strain	Chief Executive, AHWNI
Prof. Ibrahim M. Banat	Professor of Microbial Biotechnology, Ulster University

List of Abbreviations

ADS	ADS Group (Aerospace, Defence, Security and Space trade organisation)
AFBI	Agri-Food and Biosciences Institute
AMIC	Advanced Manufacturing Innovation Centre
AMR	Antimicrobial Resistance
ARC	Australian Research Council
ARMi	Advanced Regenerative Manufacturing Institute
ATI	Aerospace Technology Institute
BEIS	Department for Business, Energy and Industrial Strategy (now DSIT)
BioMADE	Bioindustrial Manufacturing and Design Ecosystem (US)
BIRAC	Biotechnology Industry Research Assistance Council (India)
CAR-T	Chimeric Antigen Receptor T-cell
CDHT	Centre for Digital Healthcare Technology
CDMO	Contract Development and Manufacturing Organisation
CGT	Cell and Gene Therapy Catapult
CGTC	Cell and Gene Therapy Catapult
CPI	Centre for Process Innovation
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
D2N+	Digital Design Network Plus
DAERA	Department of Agriculture, Environment and Rural Affairs
DfE	Department for the Economy (Northern Ireland)
DoH	Department of Health (Northern Ireland)
DSIT	Department for Science, Innovation and Technology (UK)
EMA	European Medicines Agency
EPSRC	Engineering and Physical Sciences Research Council
FMI	Future Medicines Institute
GNI	Gross National Income
GVA	Gross Value Added
HIRANI	Health Innovation Research Institute Northern Ireland
HVM	High Value Manufacturing
IB	Industrial Biotechnology
IBioIC	Industrial Biotechnology Innovation Centre (Scotland)
IfM	Institute for Manufacturing, University of Cambridge
IMPACT	Irish Medicines – Personalised Advanced Cellular Therapies
INI	Invest Northern Ireland
KTP	Knowledge Transfer Partnership
LIPF	Large-Scale Innovation for Places Fund

MDC	Medicines Discovery Catapult
MHRA	Medicines and Healthcare products Regulatory Agency
mRNA	Messenger Ribonucleic Acid
NEBP	National Engineering Biology Programme
NI	Northern Ireland
NIBEC	Northern Ireland Biomedical Engineering Centre
NIBRT	National Institute for Bioprocessing Research and Training (Ireland)
NIFAB	Northern Ireland Food Animal Bioinformatics
NIPA	Northern Ireland Polymers Association
NSF	National Science Foundation (US)
PHA	Polyhydroxyalkanoate
PHB	Polyhydroxybutyrate
QUB	Queen's University Belfast
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RIED	Re-Imagining Engineering Design
RQF	Regulated Qualifications Framework
SEUPB	Special EU Programmes Body
siRNA	Small Interfering Ribonucleic Acid
STAR	Science and Technology Innovation Board (Shanghai Stock Exchange)
TRL	Technology Readiness Level
UKRI	UK Research and Innovation
UU	Ulster University

A stylized, teal-colored DNA double helix structure is the central focus of the image. It is set against a solid teal background. The helix is shown in a perspective view, curving from the top left towards the bottom right. The two strands are connected by horizontal rungs representing base pairs. The overall aesthetic is clean and scientific.

Introduction and Context

Chapter 1: Introduction and Context

1.1 Project Background and Objectives

Matrix, on behalf of the Department for the Economy (DfE), commissioned this research study to examine the opportunities emerging from engineering biology for Northern Ireland. The study assessed the region's strengths, gaps, and opportunities in this family of technologies. Through a systematic foresight approach, the research sought to understand potential economic benefits, identify strategic opportunities, and inform the planning of sustainable long-term growth regarding engineering biology. This report presents the findings, analysis, and recommendations arising from that study.

Strategic Context

In Northern Ireland, engineering biology is gaining momentum, with significant contributions from local universities and research centres. The field addresses pressing global challenges such as climate change, food security, and health crises, offering innovative solutions with substantial economic and societal benefits.

Objectives of the Research

The study was designed to:

- **Provide Current Capability Overview:** To map the current engineering biology activity in Northern Ireland, identifying key stakeholders, research strengths, and industry capabilities.
- **Conduct Preliminary SWOT Analysis:** To assess the economic impact and innovation opportunities arising from its applications. To identify challenges, support mechanisms, and strategic opportunities for growth and investment.
- **Make Recommendations:** To provide actionable recommendations to inform policy, funding, and support sector growth and resilience.
- **Recommend Future Research Opportunities:** Suggest areas that would benefit from more in-depth foresight research and strategic initiatives.

Scope of Work

- Define the engineering biology opportunity with relevance to Northern Ireland's context. Identify and profile key players, including academic institutions, businesses, and public sector organisations.
- Assess the current and potential economic impact of the application of these technologies. Review existing support mechanisms, funding streams, and collaborative networks.
- Highlight barriers to growth, including regulatory, skills, and infrastructure challenges.
- Benchmark Northern Ireland's position relative to other UK and international regions.

1.2 What is Engineering Biology?

Engineering biology is a strategic priority area of research for UK Research and Innovation (UKRI) and has been identified by the UK Government as one of five critical technologies for the nation's future.¹ It is an interdisciplinary field that spans the entire innovation ecosystem, from breakthrough synthetic biology research through to translation and application.

UKRI defines engineering biology as “an evolution of synthetic biology. It (Engineering biology) encompasses the wider capabilities of the biosciences, engineering and the physical sciences to support the exploitation of synthetic biology knowledge for economic and public benefit.”²

The UK Government's National Vision for Engineering Biology (December 2023) further defines the field as “the design, scaling, and commercialisation of biology-derived products and services that can transform sectors or produce existing products more sustainably.”³ This landmark vision, backed by £2 billion of public investment over the next decade, positions engineering biology alongside quantum technologies, artificial intelligence, semiconductors, and future telecommunications as one of five critical technologies in which the UK seeks to establish global leadership.

As engineering biology matures and moves closer to application across a wide range of sectors, it increasingly draws on insight from a broad range of disciplines such as environmental science, biomedicine, economics, and social sciences. The field harnesses the capabilities of organisms, processes, and mechanisms that exist in nature, applying engineering tools and principles to design and engineer novel biologically based parts, devices, and systems that do not exist in the natural world, as well as the redesign of existing natural biological systems for useful purposes.⁴

The applications of engineering biology are diverse and far-reaching. Early examples of the technology's transformative potential include lifesaving mRNA vaccines, cultivated meat, and the conversion of waste into aviation fuel. Across four broad application domains, the technology offers solutions to some of the most pressing challenges of our time:

- **Biomedicine and Health:** Novel diagnostics, advanced therapeutics, gene therapies, personalised medicine, and engineered biosensors for disease detection (e.g. CAR-T cell therapies using reprogrammed immune cells to treat cancer, companion diagnostics for personalised treatment, and engineered antibodies for targeted drug delivery).
- **Agriculture and Food Systems:** Precision breeding, engineered soil microbiomes, alternative proteins, and sustainable food production methods that enhance food security and resilience (e.g. rumen microbiome manipulation to reduce livestock methane emissions, precision breeding of climate-resilient crops, and bio-based food packaging from engineered microorganisms).
- **Clean Growth and Industrial Biotechnology:** Bio-based manufacturing, green chemistry, biofuels, bioplastics, and sustainable materials production through engineered microorganisms (e.g. enzyme engineering for sustainable industrial processes, biocatalysis for green chemistry applications, and microbially produced biofuels).

¹ UKRI, “Engineering Biology – Area of Investment and Support,” UK Research and Innovation. Available at: <https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/engineering-biology/> (Accessed: 26 March 2026)

² UKRI, “Engineering Biology,” UK Research and Innovation. Available at: <https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/engineering-biology/> (Accessed: 26 March 2026)

³ Department for Science, Innovation and Technology, “National Vision for Engineering Biology,” HM Government, December 2023. Available at: <https://www.gov.uk/government/publications/national-vision-for-engineering-biology> (Accessed: 26 March 2026)

⁴ EPSRC, “Synthetic Biology – Research Area,” UK Research and Innovation. Available at: <https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/synthetic-biology/> (Accessed: 26 March 2026)

- **Environmental Solutions:** Bioremediation of polluted environments, carbon capture through engineered organisms, wastewater treatment, and ecosystem health monitoring (e.g. bacteriophage-based bioremediation of contaminated waterways, biosensors for real-time water quality monitoring, and engineered organisms for nutrient removal from agricultural waste).

The UK has established itself as a global leader in engineering biology, ranked second only to the United States for research output and commercial activity⁶. Since 2007, UKRI has invested over £800 million in engineering biology, and the National Engineering Biology Programme (NEBP), developed through extensive stakeholder consultation in 2020, provides the overarching strategic framework for coordinating investment and activity across the UK's engineering biology ecosystem.⁵ Through the Technology Missions Fund, UKRI has deployed over £125 million in mission-led engineering biology investments, including six mission hubs, twenty-two mission awards, and forty-eight collaborative research and development projects.⁶

It is within this national and global context that the present study examines the specific opportunities, capabilities, and strategic positioning of Northern Ireland in the engineering biology landscape.

1.3 Northern Ireland Context and the Windsor Framework

Northern Ireland occupies a distinctive position in the post-Brexit landscape, one that creates both significant opportunities and notable complexities for emerging sectors like engineering biology. The Windsor Framework, which came into effect on 1 January 2025,⁶ replaced the Northern Ireland Protocol and fundamentally reshaped Northern Ireland's relationship with both the UK and EU regulatory systems. By maintaining alignment with certain EU regulations while remaining part of the UK's regulatory and customs territory, the Framework creates a dual-access arrangement with profound implications for life sciences and biotechnology.

Under this arrangement, medicines are now licensed on a UK-wide basis by the MHRA, providing regulatory clarity, while Northern Ireland companies can potentially access both the UK market (population: 69 million, 2024 estimate) and the EU Single Market (population: 450 million, 2024 estimate). However, the Windsor Framework also introduces notable challenges – most significantly, Northern Ireland remains aligned with EU GMO regulations while Great Britain has diverged through the Genetic Technology (Precision Breeding) Act 2023. The implications vary considerably across engineering biology's four application domains, as summarised in Table 1.

⁵ Government Science and Engineering Blog, "Celebrating the Year of Engineering Biology at UKRI," June 2025. Available at: <https://government-science-and-engineering.blog.gov.uk/2025/06/30/celebrating-the-year-of-engineering-biology-at-ukri/> (Accessed: 26 March 2026)

⁶ UK Government, "The Windsor Framework". Available at: https://assets.publishing.service.gov.uk/media/63fccc07e90e0740d3cd6ed6/The_Windsor_Framework_a_new_way_forward.pdf (Accessed: 26 March 2026)

Table 1: Windsor Framework Implications for Engineering Biology Domains

Domain	Opportunities	Constraints
Healthcare & Medicine	Medicines now licensed UK-wide by MHRA, providing regulatory clarity. Dual market access enables products to reach both UK and EU markets. Strong existing pharmaceutical sector provides a foundation.	Higher dual-compliance costs for products requiring both UK and EU approval. Policy uncertainty may deter long-term investment in development cycles.
Agri-Food & Environment	Non-GM approaches (marker-assisted breeding, microbiome applications, precision agriculture using sensors and data) can proceed without regulatory barriers. Potential to position for EU regulatory evolution on New Genomic Techniques.	Most constrained domain. NI remains aligned with EU GMO regulations – precision-bred crops approved in England under the Genetic Technology (Precision Breeding) Act 2023 cannot be grown in NI. Field trials and commercialisation of GM crops are effectively blocked. Research at TRL 4-6 faces direct barriers.
Industrial Biotechnology	Microbial production of biopolymers, chemicals, and materials faces less regulatory complexity than agricultural applications. Waste valorisation through engineered organisms benefits fully from dual market access.	Cost competitiveness of bio-based materials vs synthetic alternatives remains a challenge regardless of regulatory framework.
Environmental Solutions	Contained-use applications (fermentation-based production, cell-free diagnostic systems, bioremediation in controlled settings) face relatively aligned regulatory frameworks across UK and EU.	Open-environment deployment of engineered organisms (e.g. for bioremediation) may face additional scrutiny under EU-aligned regulations in NI.

Despite the UK's substantial national investment in engineering biology, Northern Ireland has yet to secure a proportionate share. None of the six UKRI engineering biology mission hubs are led from the region, and no life sciences Catapult has a presence in Northern Ireland. Stakeholders consistently reported that the region has historically underperformed in accessing competitive UK-wide funding – a gap that represents both a challenge and an opportunity.

1.4 Guide to This Document

This report presents the findings, analysis, and recommendations of the Engineering Biology Research Project in Northern Ireland. It is structured to guide the reader from context and methodology through evidence and analysis to strategic recommendations.

Chapter 1: Introduction and Context (this chapter) sets the scene by outlining the project background and objectives, defining engineering biology as a field, and establishing the Northern Ireland context, including the regulatory implications of the Windsor Framework.

Chapter 2: Methodology describes the research approach adopted for this study, centred on the Cambridge strategic roadmapping framework. It details the literature review and global landscape process, the design and execution of stakeholder engagement activities (interviews and surveys), the workshop process and facilitation, the synthesis and validation methods, the opportunity and feasibility scoring approach, and the quality assurance framework applied throughout.

Chapter 3: Global Landscape Insights provides an international comparative analysis examining global trends and drivers shaping the engineering biology landscape, the UK's national engineering biology strategy, insights from seven comparator jurisdictions, all-island perspectives, and key lessons for Northern Ireland drawn from this analysis.

Chapter 4: Stakeholder Engagement presents the findings from two complementary strands of primary data collection: semi-structured interviews with senior figures across academia, industry, and government, and an online stakeholder survey. Together, these instruments provide the evidence base that informed the strategic roadmapping workshop and the final recommendations.

Chapter 5: Strategic Landscape Analysis presents the core analytical output of the project, structured around the three dimensions of the roadmapping framework: Why (trends, drivers, and opportunities), What (applications, capabilities, products, and services), and How (resources, technologies, and enablers). This chapter presents the cluster inventories for each layer, the workshop prioritisation results, and the overall landscape summary identifying the highest-priority themes.

Chapter 6: Topic Roadmaps and Cases develops detailed topic roadmaps for the six priority areas identified through the landscape analysis and workshop prioritisation. These case studies cover Food Security and Resilience; Scale-Up Capabilities; Circular Bioeconomy; Agri-Tech Innovation and Policy Alignment; Diagnostics and Biosensors; and One Health.

Chapter 7: SWOT Analysis synthesises the evidence gathered throughout the study into a structured assessment of Northern Ireland's Strengths, Weaknesses, Opportunities, and Threats in engineering biology, incorporating the opportunity-feasibility scores assigned by workshop participants to each of the six priority initiatives.

Chapter 8: Recommendations and Implementation translates the analysis into actionable policy recommendations, investment priorities, and future research opportunities designed to position Northern Ireland as a competitive player in the engineering biology sector. It concludes with an indicative phased implementation framework spanning foundation, capability building, scale and integration, and cluster maturity.

The report is supported by several annexes providing supplementary details, including the detailed narrative analysis of each cluster in the strategic landscape roadmap.



Methodology

Chapter 2: Methodology

This chapter describes the research methodology adopted for the Engineering Biology Research Project in Northern Ireland. The approach centres on proven roadmapping methodologies developed at the University of Cambridge, combining strategic analysis with stakeholder engagement. The methodology integrates a futures toolkit—including horizon scanning, SWOT analysis, driver mapping, Delphi methods, and strategic roadmapping—to deliver actionable insights that position Northern Ireland for success in engineering biology. The project was delivered through five interconnected workstreams, each structured around the roadmapping framework to ensure coherence from evidence gathering through to final recommendations, as shown in Figure 1.

2.1 Cambridge Roadmapping Approach

This project places strategic roadmapping at the heart of its foresight approach. Roadmapping is a structured visual method for supporting strategy and innovation, developed and refined over more than twenty-five years by the Centre for Technology Management at the Institute for Manufacturing (IfM), University of Cambridge. Unlike conventional strategic planning tools that tend to focus on isolated elements of an organisation’s environment, roadmapping provides an integrative framework that connects different dimensions of strategic thinking into a coherent, time-based visual narrative. The approach enables the simultaneous consideration of external drivers, organisational capabilities, and the resources needed to bridge the gap between the present and a desired future state.

The approach has been applied successfully across more than 300 organisations and sectors worldwide, spanning product development, corporate strategy, sector-level foresight, and national policy initiatives (Phaal et al., 2004)⁷. Notable applications directly relevant to this study include the pioneering UK Synthetic Biology Roadmap, the UK High Value Manufacturing Strategy for Innovate UK and BEIS, the Cancer Research UK Early Detection and Diagnosis Roadmap (published in *The Lancet Oncology*), and the Advanced Manufacturing Innovation Centre (AMIC) Strategic Roadmap for Belfast City Region.

At its core, a roadmap is “a structured visual chronology of strategic intent” (Kerr and Phaal, 2022)⁸. It serves not merely as a static plan but as a navigational tool that supports strategic dialogue, insight generation, and decision-making. Critically, much of the value of roadmapping lies in the process itself through bringing together diverse stakeholders to share knowledge, surface assumptions, and build consensus around a shared view of the future. Roadmaps should therefore be understood as *living documents* that are updated as circumstances evolve, rather than fixed blueprints.

⁷ Phaal, R., Farrukh, C.J.P. and Probert, D.R. (2004) ‘Technology roadmapping – A planning framework for evolution and revolution’, *Technological Forecasting and Social Change*, 71(1–2), pp. 5–26. doi: 10.1016/S0040-1625(03)00072-6.

⁸ Kerr, C., and Phaal, R. (2022). *Roadmapping and Roadmaps: Definition and Underpinning Concepts*. <https://doi.org/10.17863/CAM.72456>

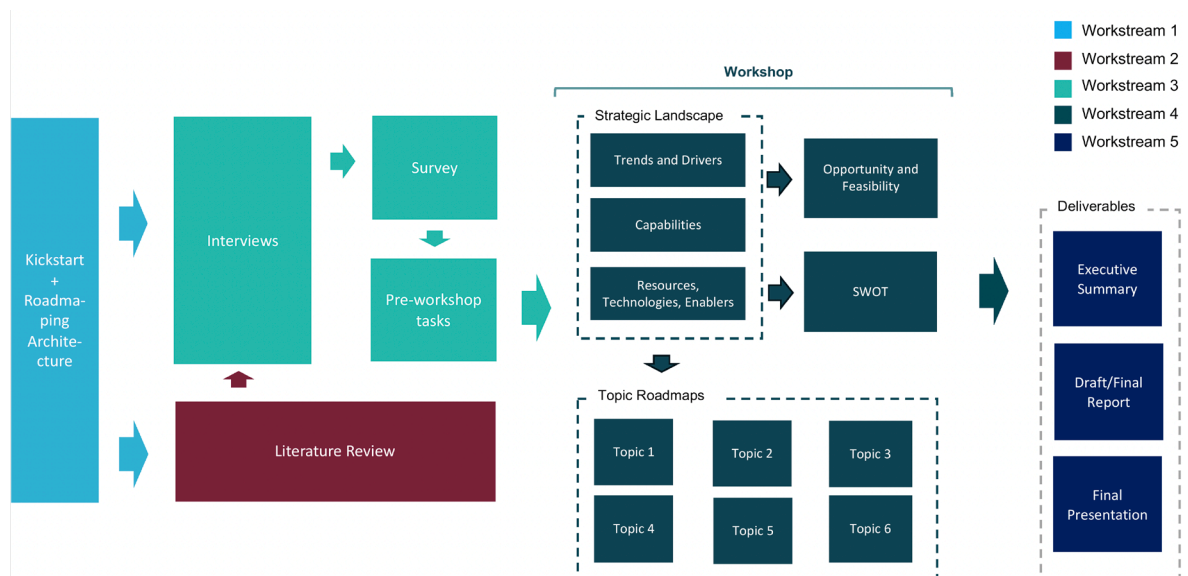


Figure 1: Project Workstreams

The Framework

The Cambridge roadmapping methodology deploys what Dr Rob Phaal, the pioneer of strategic roadmapping, describes as “the application of a temporal-spatial structured strategic lens” that integrates multiple perspectives across time horizons. The roadmap architecture serves as the central organising framework, structured around three fundamental dimensions:

- **Why** – What are the drivers, trends, and opportunities shaping the external landscape? This layer captures the forces of change that create both the imperative and the opportunity for action, including market dynamics, policy developments, societal challenges, and the competitive context.
- **What** – What applications, capabilities, products, or services can be developed in response? This layer translates external drivers into tangible areas of activity, identifying the engineering biology solutions, innovations, and value propositions that offer the greatest strategic potential.
- **How** – What resources, technologies, and enablers are required to deliver these outcomes? This layer assesses the technological capabilities and support mechanisms needed for implementation, including technology platforms, research infrastructure, skills, funding, and collaboration mechanisms.

These three layers are set against a time axis extending from past achievements through the current state to the future vision, providing a systematic canvas for capturing and synthesising the complex engineering biology landscape. The vertical connections between layers are particularly important, as they establish logical links between external drivers and the actions required to respond to them, creating coherent strategic narratives. The detailed roadmapping layers and sub-layers developed for this project are presented in Chapter 4, where they form the basis of the strategic landscape analysis.

Time Horizons

The project adopts time horizons appropriate to both the pace of development in engineering biology and the strategic planning cycles of Northern Ireland's policy environment:

- **Short-term (2026–2027):** Focusing on immediate opportunities, capability building, and quick wins. Example activities include pilot projects, skills assessments, stakeholder network formation, and small-scale infrastructure investments.
- **Medium-term (2028–2030):** Targeting strategic development, infrastructure investment, and skills pipeline development. Example activities include major research programmes, manufacturing facility upgrades, training programme establishment, and policy implementation.
- **Long-term (2031–2035):** Addressing transformational prospects and international leadership positioning. Example activities include establishing world-class research centres, achieving commercial scale-up successes, securing international partnerships, and reaching sector maturity.

A number of cross-cutting themes span all layers and time horizons, including post-Brexit opportunities and challenges, skills development and talent retention, industry-academia collaboration, regulatory frameworks and ethical considerations, investment and funding mechanisms, international competitiveness, intellectual property protection, and public engagement.

Integration with the Government Futures Toolkit

The Cambridge roadmapping methodology systematically incorporates proven foresighting techniques from the UK Government Futures Toolkit, ensuring alignment with best practice in strategic policy development. The flexibility of the roadmapping framework allows established analytical methods to be embedded within it, with each tool contributing to specific aspects of the roadmap's development. Table 1 illustrates how these methods were integrated within the project.

Table 2: Integration of Government Futures Toolkit methods within the roadmapping framework

Futures Toolkit Method	Application in the Project	Integration with Roadmapping
Driver Mapping	Identifying key forces shaping engineering biology development in Northern Ireland	Forms the 'Why' layer of the strategic landscape roadmap
Horizon Scanning	Detecting emerging technologies, weak signals, and future trends in engineering biology globally	Populates future columns of the roadmap layers
SWOT Analysis	Systematic assessment of Northern Ireland's strengths, weaknesses, opportunities, and threats	Structured input to roadmap development and workshops
Delphi Method	Expert consensus building through structured interviews and survey engagement	Validates roadmap content and priorities
7 Questions	Structured policy analysis framework applied to the engineering biology landscape	Guides stakeholder interview protocols
Scenarios	Exploring alternative future pathways for the sector	Informs roadmap branching points and strategic options

2.2 Literature Review and Global Landscape Insight

The literature review was systematically organised according to the roadmap architecture, ensuring comprehensive coverage while maintaining strategic focus. The review structure was aligned with the three roadmapping layers:

- **Market and Demand Layer ('Why')**: Analysis of global trends, market opportunities, societal challenges, and policy drivers shaping the engineering biology landscape.
- **Application Layer ('What')**: Review of engineering biology applications, products, and services relevant to Northern Ireland's priority sectors.
- **Technology and Resource Layer ('How')**: Assessment of enabling technologies, infrastructure requirements, skills gaps, and funding mechanisms.

Sources included academic literature on engineering biology advances and applications, policy documents including 10X Economy Vision for NI⁹ (succeeded by the Minister's four priorities: good jobs, regional balance, productivity, and decarbonisation), the UK Life Sciences Vision,¹⁰ the UK's Industrial Strategy¹¹, market intelligence and industry sector reports, international benchmarking studies, patent and publication analytics, and existing Northern Ireland capability audits and skills assessments. Over 200 sources were reviewed, with priority coding (high, medium, low) and cluster analysis developed according to the roadmapping framework. Temporal tagging was applied to categorise findings against the short-, medium-, and long-term horizons.

The roadmapping structure ensured that the literature review directly informed stakeholder engagement activities and workshop preparations, thereby avoiding information silos. International benchmarking examined comparator regions including Scotland, the Cambridge cluster, the Republic of Ireland, the Netherlands, and the Boston/Cambridge (US) life sciences ecosystem, with particular attention to all-island perspectives and the implications of Northern Ireland's unique positioning under the Windsor Framework. A detailed account of the global landscape findings is presented in Chapter 3.

2.3 Stakeholder Engagement Design

The stakeholder engagement strategy used the roadmap framework to ensure systematic coverage and meaningful input from across the engineering biology ecosystem. Stakeholders were identified and mapped in consultation with Matrix and the Department for the Economy, using the roadmap architecture to ensure representation across three perspectives:

- **Demand-side (Why layer)**: End-users, regulators, policy makers, and investors who shape the strategic context for engineering biology.
- **Application developers (What layer)**: Companies, entrepreneurs, and translational researchers developing engineering biology solutions.
- **Technology and resource providers (How layer)**: Universities, research institutes, and infrastructure providers who supply the enabling capabilities.

The stakeholder list encompassed dozens of contacts across academia, industry, government, policy bodies, and support organisations. The project ensured that all major stakeholders had the opportunity to contribute, that all areas of interest were given expert coverage, and that both consensus and differences in vision and opinion were captured to produce the most accurate and workable recommendations. The engagement was conducted under the

⁹ Department for the Economy (2021) *10x Economy: An Economic Vision for a Decade of Innovation*. Belfast: Department for the Economy. Available at: <https://www.economy-ni.gov.uk/articles/10x-economy-economic-vision> (Accessed: 26 March 2026)

¹⁰ UK Government (2021) "UK Life Sciences Vision". Available at: <https://assets.publishing.service.gov.uk/media/612763b4e90e0705437230c3/life-sciences-vision-2021.pdf> (Accessed: 26 March 2026)

¹¹ UK Government (2025) *The UK's Modern Industrial Strategy 2025*. Available at: https://assets.publishing.service.gov.uk/media/69256e16367485ea116a56de/industrial_strategy_policy_paper.pdf (Accessed: 26 March 2026)

Chatham House Rule. All findings from the interviews and stakeholder survey are presented thematically, without attribution to named individuals, organisations, or identifiable roles. Where views are cited, they are referenced only by broad category (e.g. ‘an academic interviewee’, ‘an industry leader’) to preserve anonymity whilst conveying the perspective from which the insight was offered. This approach was adopted to encourage candid contributions, recognising that frank assessment of the region’s strengths, weaknesses, and barriers is essential to producing actionable recommendations.

Semi-Structured Interviews

Semi-structured interviews were conducted with key stakeholders drawn from across the engineering biology ecosystem. Interview protocols were structured around the roadmap layers to ensure consistency and comprehensive coverage, with the 7 Questions framework applied for policy stakeholders and a Delphi-style iterative approach used to build consensus on priorities. Interviews were designed as structured discussions, collated to provide as complete a picture as possible of the sector, its influences, strengths, and capabilities. The ten interviewees were drawn from across the engineering biology ecosystem in Northern Ireland and provided perspectives spanning:

- **Academia (4 interviewees):** Senior research leaders in fields including neuroimmunology, food security and diagnostics, microbiology, and medicine, health and life sciences, drawn from Northern Ireland’s two main universities.
- **Industry (2 interviewees):** Senior executives from major Northern Ireland life sciences companies with global operations spanning drug development, precision medicine, diagnostics, and medical devices.
- **Government and policy (2 interviewees):** A senior UK government chief scientist with strategic oversight of national research and innovation, and a senior departmental policy lead responsible for multiple sectors relevant to engineering biology within the NI Executive.
- **Statutory research (1 interviewee):** A senior figure from Northern Ireland’s principal government research institute, with broad knowledge of EU funding programmes and regional research capabilities.
- **Innovation infrastructure (1 interviewee):** The leader of a major advanced manufacturing innovation centre in Belfast, with experience of Catapult-style models and cross-sector technology transfer.

Interviewees were drawn predominantly from healthcare and life sciences backgrounds (~40%), with representation also from industrial biotechnology and manufacturing (~20%), agri-food and environment (~20%), and cross-cutting policy roles (~20%). Triangulation with survey data, desk research, and workshop outputs was used to ensure balanced coverage across all four priority sectors. This breadth ensured that the interview findings reflect the full spectrum of stakeholder interests and experiences relevant to engineering biology in Northern Ireland. Findings from the interviews are presented in Chapter 4.

Online Survey

An online survey was designed to gather structured input from a broader cross-section of stakeholders beyond those engaged through interviews. The survey was developed on the Qualtrics platform and distributed through multiple channels, including the Matrix Panel network, Invest Northern Ireland contacts, university research offices at Queen’s University Belfast and Ulster University, AFBI, and the Department for the Economy. A total of sixteen completed responses were received from stakeholders spanning academia, industry, government, and the wider innovation support ecosystem.

Table 3: Survey questions

Thematic Area	Key Survey Questions	Roadmap Layer
Current Landscape and Strengths	What are NI's key strengths and capabilities in engineering biology? Which organisations are leading or have potential to lead? Where are the most significant capability gaps?	How (Resources & Capabilities)
Drivers and Trends	What market trends or drivers are driving demand? How are policy developments affecting opportunities? What societal challenges could engineering biology address?	Why (Drivers & Trends)
Promising Applications	What applications are most promising in the short term (next 2 years)? What opportunities might emerge in the medium term (3–5 years) and longer term (5–10 years)?	What (Opportunities)
Niche Opportunities	Are there particular niches or specialisms where NI could develop competitive advantage?	What (Opportunities)
Skills and Infrastructure	What skills and workforce capabilities are most needed? What research infrastructure, equipment, or support mechanisms would be most valuable?	How (Enablers)
Barriers and Priorities	What are the main barriers preventing faster growth? What would be the top three strategic priorities? What would success look like by 2035?	Cross-cutting

Respondent Profiles

The 16 survey respondents represented a diverse cross-section of the engineering biology ecosystem. The sectoral distribution was weighted towards agri-food, reflecting both the sector's significance in the Northern Ireland economy and the strong engagement from agricultural research bodies. Ten respondents identified agri-food as a primary sector, five identified healthcare and medicine, four identified industrial biotechnology, and four identified environmental solutions. Several respondents spanned multiple sectors, reflecting the inherently cross-cutting nature of engineering biology.

Respondents included senior research leaders, heads of research groups and units, university lecturers, post-doctoral researchers, senior policy officials from government departments, industry team leaders from major life sciences companies, and sector leads from UK government trade bodies. Self-described connections to engineering biology ranged from deeply embedded practitioners (biotechnologists with 40+ years' experience, molecular biologists developing gene-edited organisms) through to policy professionals with strategic oversight roles and stakeholders with limited direct involvement but relevant sectoral knowledge. Survey responses are analysed in Chapter 4.

2.4 Workshop Process and Facilitation

The strategic roadmapping workshop formed the cornerstone of the stakeholder engagement strategy, following IfM's S-Plan roadmapping approach. The workshop was held on 3 February 2026 at Belfast Metropolitan College, bringing together 35 participants from across academia, industry, government, and support organisations. Facilitated by the IfM Engage team using the Cambridge S-Plan approach, the workshop was underpinned by a pre-populated strategic landscape in which over 1,200 statements from the literature review, interviews, and survey

were clustered into thematic groups ('clusters')¹² across the three roadmapping layers: Why (trends and drivers), What (applications and capabilities), and How (resources and enablers).

Building on the outputs of the literature review and stakeholder engagement, a landscape was created and partly pre-populated ahead of the workshop, incorporating findings from interviews, surveys, and desk research. Participants received a briefing document including the scope and aims of the event, an introduction to the roadmapping process, and a short pre-work to review the draft landscape. This ensured an efficient launch point for the workshop and the steady building of consensus and buy-in.

The workshop was structured around the following activities:

- Identifying and prioritising trends and drivers, needs of key stakeholders, and challenges
- Identifying and prioritising initiatives and activities that address those trends, drivers, and needs, and capturing these within the strategic landscape
- Identifying potential solutions, skills, and capability requirements, as well as weaknesses and threats
- Tracing pathways from current capabilities to future opportunities, with integration of case studies demonstrating successful innovation journeys
- Breakout groups to develop topic roadmaps, scoping and exploring priority initiatives by identifying expectations, key stakeholders, tasks and milestones, skill and resource requirements, enablers, and foreseeable barriers or risks
- Delivery of project idea summaries by each group, followed by clarification and comments from other participants

The workshop followed a deliberate sequence: beginning with the Why layer (reviewing and validating the top drivers and trends), moving to the What layer (identifying applications and opportunities across the priority sectors), and finishing with the How layer (engaging experts to prioritise the capabilities, resources, and enablers required to realise those opportunities). This sequence ensured that resource and capability planning were firmly grounded in a shared understanding of both the external context and the specific opportunities identified.

2.5 Synthesis and Validation

The results from the strategic roadmapping workshop required careful synthesis. The strategic landscape, topic roadmaps, linkage grids, and other key information were reviewed and integrated into a comprehensive strategic roadmap. Special attention was given to the strategic landscape and topic roadmaps to detect overlaps, dependencies, and possible gaps. The synthesis process addressed:

- Linkages between the priority initiatives and sector challenges
- Dependencies between priority initiatives, key risks and potential gaps, establishing a logical sequencing of activities
- Production of coherent narratives connecting priority initiatives with needs, challenges, technologies, skills, and resources
- Confirmation and refinement of the SWOT analysis
- Identification and development of case studies

¹² The term 'cluster' as used in this report refers to thematic groupings of stakeholder statements within the roadmapping methodology. This is distinct from the policy usage of the term to describe regional concentrations of industry and innovation activity.

A preliminary SWOT analysis was developed from the literature review and pre-populated ahead of stakeholder engagement, following a hybrid approach. This draft analysis was then presented to stakeholders during interviews, surveys, and the workshop to critique, correct, and enhance –leveraging the principle that stakeholders engage more actively when responding to a concrete starting point rather than working from a blank canvas. The Why layer captured opportunities and threats from the external environment, whilst the How layer identified internal strengths and weaknesses, with the two meeting in the middle to identify strategic opportunities for growth and investment.

A small number of stakeholders were subsequently engaged to review the synthesised outcomes, validating the findings and ensuring that the final roadmaps accurately reflected the breadth of perspectives gathered throughout the project.

2.6 Opportunity and Feasibility Scoring

To move from broad strategic mapping to prioritised recommendations, a structured scoring approach was adopted. Opportunities identified through the roadmapping process were assessed using a two-dimensional framework:

- **Opportunity attractiveness:** The extent to which an opportunity aligns with external drivers, addresses identified needs, and offers significant potential impact for Northern Ireland’s engineering biology sector.
- **Feasibility:** The extent to which Northern Ireland possesses, or can realistically develop, the capabilities, resources, and enabling conditions required to pursue the opportunity within the identified time horizons.

Following the prioritisation at the roadmapping workshop, breakout groups investigated their allocated opportunities in greater depth, examining and scoring both dimensions and concluding with a clear statement about scaling potential and pathway. This scoring framework ensured that recommendations were grounded not only in strategic desirability but also in a realistic assessment of Northern Ireland’s capacity to deliver.

2.7 SWOT Analysis within the Roadmapping Framework

A distinctive feature of the Cambridge roadmapping approach is the way in which SWOT analysis is embedded directly within the layered structure, rather than being conducted as a separate exercise. The Why layer, which captures external drivers and market forces, maps naturally to Opportunities and Threats facing the sector, whilst the How layer, which assesses current resources, infrastructure, and skills, maps to Strengths and Weaknesses. In this framework, developed by Dr Rob Phaal and Dr Claire Farrukh at the IfM, the Why and How layers effectively “meet in the middle” at the What layer, where strategic opportunities for growth and investment are identified—grounded simultaneously in an understanding of external context and internal capacity. Gap analysis emerges naturally from this structure, as mismatches between external opportunities and internal capabilities become visible across the roadmap, directly informing the prioritisation of recommendations and investment areas presented in this report.

2.8 Quality Assurance

Rigour was maintained throughout the project through a structured quality assurance framework encompassing three dimensions:

Methodological rigour: Academics and experts provided oversight of the roadmapping methodology application, validation of the literature review and analysis.

Stakeholder validation: Iterative feedback loops with the Matrix steering group, validation engagement with sector representatives, and expert review of draft outputs ensured that findings were tested against the knowledge and experience of those closest to the sector.

Data quality: Triangulation across multiple sources (literature, interviews, surveys, and workshop outputs), systematic coding and categorisation, and transparent documentation of the evidence base ensured that conclusions were robust and defensible.

Through this methodology, the project delivered an evidence-based assessment of Northern Ireland's engineering biology opportunities, with clear, actionable recommendations structured as strategic roadmaps that can guide policy and investment decisions for years to come. As with any stakeholder-driven methodology, the interview and workshop evidence reflects participants' informed perspectives and may carry sectoral biases or blind spots; however, triangulation across multiple evidence streams was used to mitigate this.



Global Landscape Insights

Chapter 3: Global Landscape Insights

An international review was undertaken, aiming to understand and serve as a critical element of the wider Engineering Biology Research Project in Northern Ireland. The exercise formed part of a strategic roadmapping methodology, structured around three analytical layers – “Why” (trends, drivers and context), “What” (applications by priority sector), and “How” (resources and enablers) – designed to articulate and contextualise Northern Ireland’s emerging engineering biology capabilities relative to the rest of the UK and various international regions.

The study examined how seven comparator jurisdictions – the United States, Australia, the Netherlands, Scotland, Ireland, China, and India – are positioning themselves in this rapidly evolving field. These countries were selected to provide a range of apt comparisons, from large federal systems and state-coordinated economies to small, open economies with comparable sectoral profiles. The investigation criteria encompassed R&D intensity and investment levels, collaboration models, regulatory environments, skills availability and talent pipelines, investment climate and access to capital, and commercialisation success rates. The purpose was to identify global trends, draw out country-level insights, explore all-island dimensions, and distil practical lessons that could inform the development of an engineering biology agenda across Northern Ireland’s four priority application areas, namely healthcare and medicine, agri-food and environment, industrial biotechnology and environmental solutions.

3.1 Global Trends and Drivers

- **Up to \$4 trillion/year** potential global impact by 2030–2040 (McKinsey)¹³
- **60% of physical inputs** could be produced biologically
- **50+ governments** now have national bioeconomy strategies
- **2024 Nobel Prize in Chemistry** for work underpinning AlphaFold underscores AI-biology convergence¹⁴. AlphaFold3 is expanding its capabilities to include nucleic acid binding¹⁵.

The investigation revealed a number of powerful, converging trends shaping global investment in engineering biology. The scale of the opportunity is substantial. A McKinsey report from 2020, entitled *The Bio Revolution*, estimated that between 2030 and 2040, engineering biology could account for up to \$4 trillion per year in direct annual economic impact, with as much as sixty per cent of the world’s physical inputs potentially produced using biological means. Over fifty governments have now established national bioeconomy strategies or related initiatives, setting priorities for workforce development, value chain expansion and investment. While each jurisdiction has calibrated its approach to reflect local circumstances, several common drivers recur across the comparator countries.

Strategic competition and sovereign capability. Engineering biology is increasingly viewed through the lens of geopolitical competition. The United States, through Presidential Executive Order 14081 (September 2022)¹⁶ and the establishment of the National Biotechnology and Biomanufacturing Initiative, explicitly frames the bioeconomy in terms of economic competitiveness, national security and supply-chain resilience. China’s 14th Five-Year Plan for Bioeconomy Development similarly positions biotechnology as a sovereign capability,

13 McKinsey Global Institute (2020) *The Bio Revolution: Innovations transforming economies, societies, and our lives*. Available at: <https://www.mckinsey.com/industries/pharmaceuticals-and-medical-products/our-insights/the-bio-revolution-innovations-transforming-economies-societies-and-our-lives> (Accessed: 26 March 2026)

14 Nature (2024) ‘Chemistry Nobel goes to developers of AlphaFold AI that predicts protein structures’. Available at: <https://www.nature.com/articles/d41586-024-03214-7> (Accessed: 26 March 2026).

15 Abramson, J., Adler, J., Dunger, J., Evans, R., Green, T., Pritzel, A., Ronneberger, O., Willmore, L. et al. (2024) ‘Accurate structure prediction of biomolecular interactions with AlphaFold 3’, *Nature*, 630, pp. 493–500. doi: 10.1038/s41586-024-07487-w. (Accessed: 26 March 2026).

16 US Government (2022), Executive Order 14081 Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure American Bioeconomy. Available at: <https://www.federalregister.gov/documents/2022/09/15/2022-20167/advancing-biotechnology-and-biomanufacturing-innovation-for-a-sustainable-safe-and-secure-american> (Accessed: 26 March 2026).

inextricably linked to economic security and public health sovereignty.¹⁷ The European Union has signalled that the biotech sector could serve as a test case for EU competitiveness against the US and China, with the European Competitiveness Fund designed to invest in strategic technologies, including biotechnology. This framing of biology as strategic infrastructure represents a marked shift from earlier conceptions of biotechnology as primarily a research endeavour.

Climate and sustainability imperatives. Across all seven jurisdictions, climate action is a principal driver of engineering biology investment. Australia integrates its synthetic biology ambitions with missions to end plastic waste and enable bioenergy. Ireland’s Bioeconomy Action Plan 2023–2025 is explicitly tied to its Climate Action Plan and a national objective of climate neutrality by 2050.¹⁸ Scotland’s industrial biotechnology strategy is aligned with its net-zero 2045 target.¹⁹ The Netherlands pursues complete, circular value chains from sustainable feedstock through advanced biorefining through to market-ready products. The UK Biomass Strategy 2023 commits to developing a cross-sectoral sustainability framework for biomass, with long-term prioritisation of negative-emissions pathways through bioenergy.²⁰ In each case, engineering biology is positioned not as an end in itself but as an enabling platform for the green transition.

Mission-driven policy and long-term planning. The most effective national strategies share a commitment to mission-driven policy with clearly articulated, time-bound targets. The United States’ “Bold Goals for U.S. Biotechnology and Biomanufacturing” document sets twenty-year quantitative targets across five pillars, including displacing over ninety per cent of today’s plastics with bio-based alternatives, producing at least thirty per cent of US chemical demand via biomanufacturing, and reducing cell therapy manufacturing costs tenfold.²¹ Australia targets AUD \$30 billion in annual synthetic biology revenue and 50,000 new jobs by 2040.²⁸ India’s Draft National Biotechnology Development Strategy aims to grow the national bioeconomy from \$70 billion in 2020 to \$150 billion by 2025 and envisions a \$1 trillion bioeconomy by 2030.²² In this study, certain sub-domains – notably biomaterials – received less direct NI stakeholder input than others; in these cases, the analysis drew more heavily on UK-level data and international comparisons to ensure adequate coverage.

Convergence with artificial intelligence and digital technologies. A further recurring theme is the deliberate integration of engineering biology with artificial intelligence, data science and digital infrastructure. The significance of this convergence was underscored by the award of the 2024 Nobel Prize for AlphaFold, which offers transformative potential for predictive biological design. Industry surveys indicate that most executives consider AI important in accelerating adoption of engineering biology solutions and further believe generative AI will significantly increase R&D efficiency. China’s strategy emphasises the “integration and innovation of biotechnology and information technology” across traditional sectors. India explicitly leverages its IT sector to drive bio-innovation through bioinformatics, computational biology and AI-enabled drug discovery. The United States’ Data for the Bioeconomy Initiative establishes a national plan for shared data ecosystems to underpin bioeconomy development.

17 National Development and Reform Commission (2022) *China’s 14th Five-Year Plan (2021–2025)*. Translated by Center for Security and Emerging Technology, Georgetown University. Available at: https://csset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf (Accessed: 26 March 2026).

18 Department of Agriculture, Food and the Marine and Department of the Environment, Climate and Communications (2023) *National Bioeconomy Action Plan 2023–2025*. Dublin: Government of Ireland. Available at: <https://www.gov.ie/en/department-of-agriculture-food-and-the-marine/publications/bioeconomy-policy/> (Accessed: 26 March 2026).

19 Scottish Government (2022) National Plan for Industrial Biotechnology. Available at: <https://www.sdi.co.uk/media/ejci5hme/nationalplusplanplusfinalplusscreenpluscopy.pdf> (Accessed: 26 March 2026).

20 UK Department for Energy Security and Net Zero (2023) Biomass Strategy 2023. Available at: <https://assets.publishing.service.gov.uk/media/64dc8d3960d123000cd32c602/biomass-strategy-2023.pdf> (Accessed: 26 March 2026).

21 The White House Office of Science and Technology Policy, “Bold Goals for U.S. Biotechnology and Biomanufacturing”. Available at: <https://bidenwhitehouse.archives.gov/wp-content/uploads/2023/03/Bold-Goals-for-U.S.-Biotechnology-and-Biomanufacturing-Harnessing-Research-and-Development-To-Further-Societal-Goals-FINAL.pdf> (Accessed: 26 March 2026).

22 Ministry of Science and Technology, Government of India, “India - National Biotechnology Development Strategy (2020–2025)”. Available at: https://www.indiascienceandtechnology.gov.in/sites/default/files/file-uploads/sciencetechnologypolicies/1746188654_Draft_National_Biotechnology_Development_Strategy_2020-25.pdf (Accessed: 26 March 2026).

Industry momentum and the scaling challenge. Corporate engagement with engineering biology is accelerating. Industry data suggests the vast majority of organisations are now pursuing engineering biology solutions, with over half at pilot or scale stage. Most corporate executives agree that engineering biology will significantly disrupt their industry, either within five years or the next five to ten years, and that progress towards sustainability goals can be significantly accelerated. However, the transition from laboratory discovery to commercial-scale production remains a critical bottleneck, where key barriers include high costs, long development lead times, scaling production challenges and a lack of suitable large-scale infrastructure. Talent shortage is another major concern for corporates, reflecting the unusual combination of skills required across biological sciences, technology, engineering, and operations.

3.2 UK Engineering Biology Strategy

- **£2 billion** committed over 10 years (National Vision, Dec 2023)
- **~ 1,000 EngBio firms** raised £5.2bn (2017–2022) – most biotech start-ups in Europe
- **£100m UKRI Mission Fund** allocated in 2024 for Mission Hubs & Awards
- **House of Lords warning:** “severe danger” of falling behind without urgent action

The United Kingdom has positioned engineering biology as a strategic priority technology within its broader Science and Technology Framework. In December 2023, the Department for Science, Innovation and Technology (DSIT) published the National Vision for Engineering Biology,²³ accompanied by a commitment of £2 billion in public investment over ten years. The Vision articulates six priority areas: World-leading research and development, infrastructure, talent and skills, regulations and standards, uptake by the broader economy, and responsible and trustworthy innovation. Its ambition is for the UK to have a broad, rich engineering biology ecosystem open to ideas, private investment, talent and trade.

The UK has founded more biotechnology companies than any other nation in Europe, with around 1,000 engineering biology firms in the UK, and these firms collectively raised over £5.2 billion between 2017 and 2022.²³ The ecosystem is anchored by world-class universities and research institutions, supported by clusters across the country from Cambridge to Bristol to Edinburgh, often enabled by local infrastructure such as biofoundries. UK Research and Innovation (UKRI) has committed substantial funding through its Technology Missions Fund, with £100 million allocated in 2024 for Engineering Biology Mission Hubs and Mission Awards across themes including environmental biotechnology and preventing plastic pollution.²⁴ UKRI has also invested approximately £25.9 million in four Engineering Biology Centres for Doctoral Training since 2014, supporting over 200 studentships.²⁵

Institutional support for the strategy has deepened progressively. DSIT established an Engineering Biology Steering Group in 2024 to provide a two-way channel between government and the wider sector, drawing membership from academia, SMEs and larger industry. In December 2024, this was replaced by the Engineering Biology Advisory Panel to further strengthen governance. The Engineering Biology Regulators’ Network was launched with £5 million for regulatory sandboxes to tackle pressing regulatory challenges and create pathways for products to reach market. The Regulatory Innovation Office, established in October 2024, identified engineering biology as one of its four early priority areas. The Precision Breeding Act 2023 created a new regulatory framework for precision-bred organisms in England, distinguishing them from traditional GMOs – a significant step in enabling the application of engineering biology to agriculture and food. DSIT also committed to making the

23 Department for Science, Innovation and Technology (2023) *National vision for engineering biology*. London: HM Government. Available at: <https://www.gov.uk/government/publications/national-vision-for-engineering-biology> (Accessed: 26 March 2026).

24 UK Research and Innovation (2024) *New £100m fund will unlock the potential of engineering biology*, 9 February. Available at: <https://www.ukri.org/news/new-100m-fund-will-unlock-the-potential-of-engineering-biology/> (Accessed: 26 March 2026).

25 UK Research and Innovation (2024) *£1 billion doctoral training investment announced*. Available at: <https://www.ukri.org/news/1-billion-doctoral-training-investment-announced/> (Accessed: 26 March 2026).

UK a world leader in responsible innovation by 2030, commissioning its first public attitudes survey in August 2024, surveying 3,000 UK adults and found low public awareness but broadly positive attitudes towards engineering biology applications.

Significant challenges remain, however. In January 2025, the House of Lords Science and Technology Committee published a report²⁶ which delivered a sobering assessment. The Committee warned that the UK had already lost ground as a world leader and was in “severe danger” of slipping further behind without urgent action. The report identified a persistent failure to translate scientific excellence into commercial success, with pioneering companies frequently relocating abroad in search of better investment and development conditions. Critical gaps were identified in scale-up infrastructure, access to growth-stage capital, and doctoral training provision – with only two new engineering biology doctoral training programmes in 2024, compared to thirteen in AI. The wider biotech funding environment has also tightened, with thirty-nine per cent of biotechs assessed in 2024 projected to run out of cash within twelve months, the highest level in at least six years.

The Committee’s recommendations called for engineering biology to feature prominently in the forthcoming Industrial Strategy, for the establishment of multidisciplinary Biomanufacturing Innovation Centres for non-health applications, and for a coordinated cross-government approach to skills, regulation, infrastructure and investment. The government’s response, published in March 2025, acknowledged the significant potential of engineering biology, but the Committee’s assessment underscored a recurring tension in UK innovation policy, namely world-class research capability coupled with insufficient capacity to scale and commercialise domestically. For this investigation, the UK’s national strategy provides an important contextual frame. Northern Ireland operates within this broader UK policy landscape yet has its own devolved responsibilities for economic development, skills and innovation. The Windsor Framework further shapes Northern Ireland’s regulatory position, securing a UK-wide regime for the approval and supply of medicines under MHRA authority while maintaining certain dual-market access arrangements. Understanding both the opportunities afforded by UK-level investment and the specific gaps identified in the national strategy is essential for calibrating an effective regional approach.

3.3 Country Brief Insights

The study examined seven jurisdictions, each offering distinct models and lessons for Northern Ireland. This section provides a concise synthesis of the key characteristics and strategic approaches observed in each.

Scotland

- **IBioIC hub model:** centralised coordination since 2014; £50m+ invested in innovation
- **Growth:** 43 → 147 active companies; turnover £189m → £797m (2012–2020)
- **2035 target:** £25bn life sciences sector, up from £10.5bn
- **Delivery sprints** and local feedstock value chains (whisky, marine biomass)

Scotland offers a relevant comparator for Northern Ireland, given it is also a constituent part of the UK, with devolved governance and a strong agri-food heritage. The Industrial Biotechnology Innovation Centre (IBioIC), established in 2014 as a European centre of excellence for industry-led research, serves as a dedicated, centralised coordination hub, providing a focal point for strategy delivery, industry-academic collaboration and skills development.

²⁶ House of Lords Science and Technology Committee (2025) *Don't Fail to Scale: Seizing the Opportunity of Engineering Biology*, HL Paper 113. London: The Stationery Office.

Scotland's approach is distinguished by its use of measurable roadmaps with regular progress reviews. In the 2022 strategy update, the sector was found to be ahead of schedule against its original targets, prompting the creation of new "stretch targets": 220 active IB companies, £1.2 billion turnover, and over 4,000 direct employees by 2025.¹⁹ By 2020, the number of active companies had grown from 43 in 2012 to 147, with sector turnover increasing from £189 million to £797 million. The most recent Life Sciences Strategy for Scotland sets an ambitious goal of becoming a £25 billion life sciences sector by 2035, up from the current £10.5 billion turnover, with a new industry-led cluster development organisation to drive delivery.²⁷

Key features of the Scottish model include the building of value chains around local feedstocks such as whisky co-products and marine biomass, the use of NHS Scotland as a testbed and partner for pilot initiatives (including NHS Regional Innovation Hubs), targeted skills gap analyses to support the talent pipeline, and the explicit alignment of the strategy with Scotland's net-zero 2045 ambition. Investment in physical infrastructure is also significant. The Falkirk Growth Deal includes £10 million for a bioeconomy accelerator pilot plant as part of a Sustainable Chemicals Campus at Grangemouth, integrated with a Carbon Dioxide Utilisation Centre. The strategy to 2035 introduces focused "delivery sprints" – clearly defined actions over one-to-three-year periods – alongside plans to attract inward investment and foster global partnerships, and the launch of AI Scotland in 2026 to accelerate life sciences innovation.

United States

- **Executive Order 14081:** whole-of-government initiative; 5+ departments coordinated
- **Bold Goals:** 30% of chemicals via biomanufacturing; 90% plastics displaced (20-yr targets)
- **World's deepest VC markets** for biotech; BioMADE and ARMI institutes

The United States views engineering biology through the prisms of economic competitiveness, national security and societal resilience. Policy is driven by high-level political mandates, principally Presidential Executive Order 14081, which established a whole-of-government National Biotechnology and Biomanufacturing Initiative, with supporting legislation through the Bioeconomy R&D Act of 2020. Multiple federal departments – including Defence, Energy, Agriculture, Commerce, Health and Human Services, and the National Science Foundation – are developing sector-specific strategies. The "Bold Goals" document sets ambitious twenty-year quantitative targets, including producing at least thirty per cent of US chemical demand via sustainable biomanufacturing, displacing more than ninety per cent of today's plastics with bio-based polymers, and sequencing one million microbial genomes in five years. The strategy also encompasses regulatory clarity initiatives, biosafety and biosecurity innovation, workforce development and a comprehensive threat assessment of foreign adversary acquisition of US biotechnologies.

The US ecosystem benefits from the world's deepest venture capital markets for biotechnology, a substantial network of federally funded research centres, manufacturing innovation institutes such as BioMADE and the ARMI BioFabUSA Tissue Foundry, and the Data for the Bioeconomy Initiative establishing a national plan for shared data infrastructure.

²⁷ Life Sciences Scotland and Scottish Government (2025) *Life Sciences Strategy for Scotland: 2035 Vision – Accelerating Growth, Driving Innovation*. Edinburgh: Scottish Government. Available at: <https://www.lifesciencesscotland.com/life-sciences-strategy-for-scotland> (Accessed: 26 March 2026).

Australia

- **CSIRO-led** coordination via Synthetic Biology Future Science Platform
- AUD \$30bn revenue, 50,000 jobs by 2040 target
- \$1.3bn Modern Manufacturing Initiative; \$540m in Trailblazer consortia

Australia's approach is heavily science-led, with the national science agency CSIRO playing a strong coordinating role through its Synthetic Biology Future Science Platform. The national vision aims to generate AUD \$30 billion in annual revenue and create over 50,000 new jobs by 2040 from synthetic biology, aligned with priorities around circular economy, sovereign capability building and leveraging the country's unique biodiversity²⁸. Major funding is directed through large, mission-driven consortia, including the Trailblazer Universities Program's Food and Beverage Accelerator (\$160 million) and the REACH recycling hub (\$380 million), alongside the \$1.3 billion Modern Manufacturing Initiative.²⁹ Skills development is integrated into research programmes through ARC Centres of Excellence, combining PhD training with industry placements. Engineering biology is deliberately integrated with adjacent national missions, including ending plastic waste, enabling the bioenergy roadmap and supporting the National Hydrogen Strategy. The Australian model illustrates the value of a strong national science agency as a coordinating anchor and the embedding of engineering biology within broader economic transition strategies.

Netherlands

- **€30bn annual opportunity by 2040** (Government Vision on Biotechnology)
- **Triple-helix model:** co-created Knowledge and Innovation Agendas
- **Campus ecosystems** (Brightlands Chemelot, Green Chemistry Campus) for scale-up

The Netherlands has published a dedicated Government Vision on Biotechnology 2025–2040, with the goal of harnessing a €30 billion annual opportunity by 2040.³⁰ The Dutch model is characterised by deep “triple-helix” collaboration between government, industry, and academia, manifested in the co-creation of Knowledge and Innovation Agendas across societal themes including health, agriculture and the circular economy. Specialised physical hubs such as Brightlands Chemelot Campus and the Green Chemistry Campus serve as ecosystems for scaling innovations. A distinctive feature is the focus on developing complete, circular value chains – from sustainable feedstock through advanced biorefining to market-ready products – alongside the concept of the “carbon chain” to prioritise high-value uses of biomass. Skills development is integrated within the Knowledge and Innovation Agendas as a foundational enabler, and there is an explicit focus on converging engineering biology with other key enabling technologies. Proactive public engagement is recognised as a precondition for success. The overall picture is one of strategic coherence, deep multi-stakeholder collaboration and the deliberate integration of research, skills, infrastructure and market creation within a single policy framework.

28 CSIRO and Main Sequence Ventures (2024) *Synthetic Biology National Progress Report*. Canberra: Commonwealth Scientific and Industrial Research Organisation. Available at: [https://www.csiro.au/en/news/all/news/2024/february/synthetic-biology-advances-to-generate-\\$30b-opportunity-for-australia](https://www.csiro.au/en/news/all/news/2024/february/synthetic-biology-advances-to-generate-$30b-opportunity-for-australia) (Accessed: 26 March 2026)

29 Australian Government, “Modern Manufacturing Initiative”. Available at: <https://www.industry.gov.au/news/modern-manufacturing-initiative-and-national-manufacturing-priorities-announced> (Accessed: 26 March 2026)

30 Government of the Netherlands (2025), *Government's vision on Biotechnology 2025 - 2040*. The Hague: Government of the Netherlands. Available at: https://www.government.nl/binaries/government/documenten/reports/2025/04/11/dutch-vision-on-biotechnology-2025-2040/Dutch+vision+on+biotechnology+_ENGLISH.pdf

Ireland

- **€100bn in exports;** 84,000 employed; 11th on EU Innovation Scoreboard
- BiOrbic, NIBRT, Lisheen Campus – key institutional assets
- **Strategic themes 2023–2027:** Industry 5.0, cell & gene therapy, CDMO growth

Ireland's approach is anchored in its Bioeconomy Action Plan 2023–2025,³¹ explicitly tied to the Climate Action Plan and the National Smart Specialisation Strategy. The bioeconomy sector is worth approximately €100 billion in exports, employing over 84,000 people, with Ireland ranking 11th on the European Innovation Scoreboard.

The strategy benefits from a strong biopharma manufacturing base. Ireland is a global leader in commercial-scale production of biologics, vaccines and advanced therapies. Notable institutional assets include BiOrbic, a bioeconomy research centre with over 100 researchers, and NIBRT, which provides cutting-edge bioprocessing training to a global standard. The National Bioeconomy Campus at Lisheen in Co. Tipperary has received €5 million through the EU Just Transition Fund for the BioScaleUp initiative. The Smart Specialisation Strategy incorporates green transformation for enterprise as a national priority, with strategic themes for 2023–2027 including Industry 5.0 digitalisation, cell and gene therapies, and contract development and manufacturing organisation (CDMO) sector growth. The Irish model is particularly instructive for its integration of engineering biology within climate and regional development policy, its leveraging of existing industrial strengths and its focus on moving from pilots to commercialisation.

China

- **\$3bn → \$380bn** biopharma market cap growth in 5 years (STAR Market)
- 52.4% of world's top-cited synthetic biology papers
- **Dual-track regulation:** fast-track for state priorities; strict on data & genetic resources

China takes a state-coordinated, scale-driven approach. The 14th Five-Year Plan¹⁷ for Bioeconomy Development establishes clear 2025 and onwards targets, positioning the bioeconomy as a key driving force for national growth. Policy explicitly aims to cultivate “national champions,” with targets for companies exceeding ¥1 billion (~£107 million) in annual revenue. Dedicated capital market channels, including Shanghai's STAR Market, have fuelled the biopharma sector's growth from \$3 billion to \$380 billion in market capitalisation in five years. China now produces 52.4 per cent of the world's top-cited synthetic biology papers, with the Ministry of Science and Technology running dedicated programmes, including a 2023 synthetic biology key special project offering ¥17.6 million per project. The state's approach emphasises the integration of biotechnology with digital and industrial policy as a horizontal enabler across agriculture, materials, energy, and environmental protection. Regulation operates on a dual track. It is highly supportive for innovations aligned with state priorities but tightly controlled regarding data flows and genetic resources through a comprehensive bio-security law enacted in 2021. While not directly transferable, China's model demonstrates the transformative potential of long-term policy certainty and scale-driven investment.

31 Government of Ireland (2023) *Bioeconomy Action Plan 2023–2025*. Dublin: Department of Agriculture, Food and the Marine and Department of the Environment, Climate and Communications. Available at: <https://assets.gov.ie/273984/64aa20ef-3907-46fe-a599-73ba208a1edf.pdf>

India

- \$1 trillion bioeconomy target by 2030; “Mission Mode” programmes
- **5,300+ biotech startups** supported by BIRAC (\$250m+ in venture funds)
- **“Bio-Services” concept:** value in knowledge-intensive services, not just products

India’s approach is characterised by ambitious national strategy, the leveraging of unique local assets – including a vast bio-resource base and world-class IT capability – and a strong focus on affordable innovation and inclusive growth. The Draft National Biotechnology Development Strategy 2020–25³² outlines a quantified vision to reach a \$1 trillion bioeconomy by 2030, executed through focused “Mission Mode” programmes in biopharma, bio-agriculture, bio-industrial and the distinctive concept of “bio-services”, which encompasses contract research, environmental biotechnology and bio-IT, and recognises that economic value extends beyond products to knowledge-intensive services. The Biotechnology Industry Research Assistance Council (BIRAC) manages over \$250 million in public venture funds, supporting over 5,300 biotech startups, with 1,300 added in 2021 alone. The Bio-Manufacturing and Innovation Platform provides shared infrastructure for bioprocess development and scale-up, reducing capital risk for startups and SMEs. India also conducts robust annual benchmarking through its India Bioeconomy Report, providing a best-practice model for data-driven policy adjustment. The emphasis on “frugal innovation” offers a complementary perspective to the capital-intensive models observed elsewhere.

3.4 All-Island Perspectives

- **Shared agri-food base** and cross-border supply chains already in operation
- **Windsor Framework:** dual UK-EU market access as competitive advantage
- **BiOrbic, NIBRT, Lisheen Campus** available for cross-border partnership

The analysis identified significant potential for all-island collaboration in engineering biology, building on existing cross-border relationships and shared challenges. Ireland’s Bioeconomy Action Plan 2023–2025 explicitly acknowledges this dimension, noting that Ireland and Northern Ireland face very similar climate and sustainability challenges, share similar agriculture, land use and marine activities, and have developed close cross-border stakeholder collaborations over time. As the Action Plan observes, some bioresources – such as fish stocks – are clearly not confined within borders, making collaboration on the bioeconomy a natural extension of existing partnerships.

Several structural factors make the all-island dimension particularly compelling. Both jurisdictions share agri-food as a dominant economic sector. In Northern Ireland, the food and drinks processing sector alone had a gross turnover of £6.5 billion in 2022 (provisionally £7.1 billion in 2023), employing over 25,500 people and contributing 35.5% of total manufacturing sales³³. In the Republic of Ireland, agri-food accounted for 5.4% of GNI (€17.4 billion) and 6.2% of employment in 2024, with food exports valued at €19 billion³⁴. Both jurisdictions have comparable livestock-dominated feedstock bases and supply chains that already operate on a cross-border basis. Both face acute climate and environmental pressures for which engineering biology offers potential solutions, and both have relatively small domestic markets, meaning collaboration offers economies of scale in research infrastructure, skills development and market access. Northern Ireland’s unique regulatory position under the Windsor Framework adds a further dimension. The Framework secures a UK-wide regime for the approval and supply of medicines under MHRA authority, while certain dual-market access

³² Department of Biotechnology (2020) *Draft National Biotechnology Development Strategy 2020–2025*. New Delhi: Ministry of Science and Technology, Government of India. Available at: https://www.indiascienceandtechnology.gov.in/sites/default/files/file-uploads/sciencetechnologypolicies/1746188654_Draft_National_Biotechnology_Development_Strategy_2020-25.pdf

³³ DAERA (2025) *Northern Ireland Food and Drinks Processing Report 2022*. Belfast: Department of Agriculture, Environment and Rural Affairs. Available at: <https://www.daera-ni.gov.uk/articles/size-and-performance-ni-food-and-drinks-processing-sector>

³⁴ Teagasc (2025) *Road Map Series 2030 – Overview of Irish Agriculture and Food*. Carlow: Teagasc. Available at: <https://teagasc.ie/publications/teagasc-road-map-series-2030-overview-of-irish-agriculture-and-food/>

arrangements mean that Northern Ireland's developing niche specialisations in personalised medicine, digital health, MedTech and clinical trials can potentially serve both UK and EU markets. This positioning, combined with Ireland's established biopharma manufacturing base and FDI track record, creates an opportunity for a complementary all-island proposition attractive to international investors.

The Republic of Ireland's institutional assets offer tangible opportunities. BiOrbic already operates as a multi-institutional network and could serve as a model or partner for cross-border research collaboration. NIBRT's globally recognised bioprocessing training capability represents a resource that Northern Ireland could access or replicate in partnership. The National Bioeconomy Campus at Lisheen provides pilot-scale biorefinery infrastructure that could complement emerging facilities in Northern Ireland. Ireland's National Smart Specialisation Strategy, with its regional Entrepreneurial Discovery Process, offers a framework for identifying complementary strengths across the island. Northern Ireland's established capabilities in advanced manufacturing, agri-food technology and data analytics could align with Ireland's strengths in biopharma manufacturing, bioeconomy research and marine bioresources to create a more complete all-island ecosystem. The policy environment is broadly conducive to such collaboration, but realising all-island potential will require deliberate institutional proactive measures to move beyond aspiration to operational collaboration.

3.5 Key Lessons for Northern Ireland

These lessons are drawn from the comparative analysis of international jurisdictions, the UK national strategy and the all-island context. They should be read against Northern Ireland's existing base: a life and health sciences sector contributing more than 2.5% of the region's economic output, worth £1.2 billion GVA (more than 170 firms, 19,500 jobs), over £200 million in City and Growth Deals targeting life sciences, and established research infrastructure at QUB, Ulster University (NIBEC), AFBI, NIFAB and the £100 million AMIC Factory of the Future. City and Growth Deal investments are also creating innovation platforms with direct relevance to engineering biology, including CDHT, i-REACH, Momentum One Zero, and AMIC's digital twin capabilities.³⁵

- **Institutional coordination is a common feature of successful ecosystems.** Across all comparator jurisdictions, the presence of a dedicated institutional anchor – one that convenes stakeholders, provides strategic direction and drives delivery – emerged as a defining characteristic. Scotland's IBioIC, Australia's CSIRO-led platforms and India's BIRAC each serve this function in different ways. Northern Ireland currently lacks an equivalent coordination mechanism for engineering biology.
- **Mission-driven strategies with measurable targets sustain momentum.** The most effective national strategies are organised around clear missions tied to societal challenges, supported by quantified targets and regular review cycles. Scotland's "stretch targets" and "delivery sprints," the US "Bold Goals" and India's annual bioeconomy reporting all provide accountability mechanisms that keep programmes on track. Vague ambitions without measurable milestones consistently underperform.
- **Successful jurisdictions build on existing sectoral strengths rather than starting from scratch.** Scotland leverages whisky co-products and marine biomass; Ireland leverages its biopharma manufacturing base; India leverages its IT sector. In each case, engineering biology strategies are anchored in pre-existing comparative advantages. Northern Ireland's relevant assets include QUB's Core Technology Units (genomics, flow cytometry, advanced imaging), Ulster University's Centre for Digital Healthcare Technologies (advanced biomedical engineering including stem cell research, ex vivo and in vitro work, point-of-care diagnostics, healthcare sensors, and cellular-level research on CRISPR and siRNA), Ulster University's

³⁵ Matrix, "Life & Health Sciences Northern Ireland (2024)". Available at: https://matrixni.org/wp-content/uploads/2024/12/64915-Matrix-Life-health-sciences-report_SF5_digital-Aw.pdf (Accessed: 26 March 2026)

Centre for Food and Drug Discovery (pre-clinical expertise through its Biomedical and Behavioural Research Unit, GLP toxicology development, mass spectrometry and genomics capabilities, and human intervention clinical facilities), NIFAB's livestock genome-to-phenome database, AFBI's Sustainable Agri-Food Sciences Division, and AMIC's Factory of the Future opening in 2026. The concept of building circular value chains around local feedstocks – as practised in Scotland and the Netherlands – is particularly relevant to the region's agri-food sector.

- **Skills and workforce development is treated as a foundational enabler, not an afterthought.** Skills gaps are identified as a critical bottleneck across all comparator jurisdictions, with different models adopted to address them – Scotland's targeted gap analyses, the Netherlands' integration of skills within Knowledge and Innovation Agendas, and India's inclusive skilling approach. The House of Lords report highlights severe under-provision in engineering biology doctoral training UK-wide. The NI Skills Barometer 2023–2033 identifies the largest under-supply at mid-tier level (RQF levels 3–5), with low provision of technical and professional qualifications.³⁶
- **Scale-up infrastructure is universally identified as the critical bottleneck.** The transition from laboratory to commercial production is the point at which most promising technologies stall. India's Bio-Manufacturing and Innovation Platform, Australia's mission-driven consortia, and the Netherlands' campus-based ecosystems each represent different approaches to providing shared, accessible pilot and scale-up facilities. Jurisdictions that invest in this infrastructure early see faster commercialisation outcomes. However, scale-up facilities must be underpinned by a sufficient pipeline of lower TRL research to sustain them, suggesting a phased approach that strengthens early-stage capacity before progressively building higher-TRL infrastructure. Northern Ireland's dual EU–UK market access under the Windsor Framework adds a distinctive dimension, offering a competitive proposition for attracting FDI in engineering biology manufacturing.
- **Regional strategies are most effective when nested within national frameworks.** No comparator jurisdiction operates in isolation from its national policy and funding landscape. The most successful regional approaches maximise access to national resources while developing a distinctive local proposition. Northern Ireland sits within the UK's broader ecosystem – UKRI's £100 million Technology Missions Fund, the National Vision's six priority areas, the Engineering Biology Regulators' Network – and also has access to all-island and international collaboration opportunities that most UK regions do not.
- **Public engagement and cross-border collaboration emerge as preconditions, not optional extras.** The Netherlands' proactive approach to societal dialogue and the UK's experience with GM food both demonstrate that public acceptance is essential for the successful adoption of engineering biology technologies. Separately, the all-island dimension consistently surfaces as an opportunity for complementary capabilities, shared infrastructure and greater critical mass. Ireland's Bioeconomy Action Plan signals openness to such collaboration in areas including agri-food bioprocessing, marine biotechnology and joint training programmes.

³⁶ Northern Ireland Department for the Economy (DfE), "NI Skills Barometer 2023–2033". Available at: <https://www.economy-ni.gov.uk/articles/ni-skills-barometer-2023-2033> (Accessed: 26 March 2026)

Table 4: Global Engineering Biology insight - Country Table

	United States	Australia	Netherlands	Scotland	Ireland	China	India
R&D & Public Investment	<ul style="list-style-type: none"> - DOD Biomufacturing: ≥ \$1.2B announced (2022). - Legislated R&D "Bioeconomy R&D Act" mandates sustained funding. 	<ul style="list-style-type: none"> - Trailblazer Consortia: \$160M (FaBA), \$380M (REACH). - Modern Manufacturing: \$1.3B initiative. - SynBio FSP: Core funding via CSIRO. 	<ul style="list-style-type: none"> - Top Sector Funding: Significant investment through TKIs & Mission-Driven Policy (exact annual figures not in sources). - NB: Strategic public-private co-investment is core model. 	<ul style="list-style-type: none"> - iBioIC Funding: Received multi-year government funding (exact figures not in 2019/2022 plan). - Impact: £50M+ invested in innovation, raised > £25M private (2012-2017). 	<ul style="list-style-type: none"> - Bioeconomy Action Plan: Framework for aligned funding (exact budget not in 2023-25 plan). - EU Funds: Access to Horizon Europe & ERDF. 	<ul style="list-style-type: none"> - National Plan: "14th Five-Year Plan for Bioeconomy". - Project Funding: ¥17.6M (~\$2.5M) per key synbio project (2023). 	<ul style="list-style-type: none"> - National Target: Grow bioeconomy to \$150B by 2025 (\$70B in 2020). - BIRAC: Manages ~\$250M+ seed fund for startups.
Collaboration Scale & Output	<ul style="list-style-type: none"> - Manufacturing Institutes: Network of "Manufacturing USA" institutes (e.g., BioMADE). - Agency Coordination: 5+ key departments aligned under Executive Order. 	<ul style="list-style-type: none"> - National Coordination: CSIRO's "Synthetic Biology Future Science Platform" & "BioFoundry". - Research Centres: ARC Centre of Excellence (\$35M over 7 years). 	<ul style="list-style-type: none"> - "Triple Helix" Hubs: Flagship campuses (e.g., Brightlands Chemelot). - Co-Creation: "Knowledge & Innovation Agendas" (KIAs) for 5 societal themes. 	<ul style="list-style-type: none"> - Central Hub: Industrial Biotechnology Innovation Centre (iBioIC). - Projects: Supported 48 industry/academia collaborative projects by 2019. 	<ul style="list-style-type: none"> - National Centres: BiOrbic (bioeconomy), NIBRT (biopharma training). - Smart Specialisation: "Entrepreneurial Discovery Process" for regional consortia. 	<ul style="list-style-type: none"> - State-Led Mega-Projects: Large, focused national R&D programs. - Research Dominance: 52.4% of world's top-cited synbio papers. 	<ul style="list-style-type: none"> - Mission-Mode: Sectoral missions (Biopharma, Bio-Agri). - BIRAC Ecosystem: Supports 5,300+ biotech startups.
Regulatory & Policy Targets	<ul style="list-style-type: none"> - Bold Goals (20-yr): e.g., 30% of U.S. chemicals via biomufacturing; 10-fold cost reduction for cell therapies. 	<ul style="list-style-type: none"> - National Target: SynBio to underpin A\$30B annual revenue & 50,000+ jobs by 2040 (Progress Report). 	<ul style="list-style-type: none"> - National Vision: "Government Vision on Biotechnology 2025-2040" with goal to harness €30B annual opportunity by 2040. 	<ul style="list-style-type: none"> - Sector Targets (2022 Update): >220 active companies, £1.2B turnover, >4,000 employees by 2025. 	<ul style="list-style-type: none"> - Bioeconomy Framework: Action Plan 2023-2025 with 7 pillars; aligned with national net-zero 2050 goal. 	<ul style="list-style-type: none"> - National Target: Bioeconomy a "key driving force" by 2025; be at global forefront by 2035. - Regulatory Reform: Priority drug reviews rose from 14% to 77% (2016-2019). 	<ul style="list-style-type: none"> - Draft Strategy: National Biotechnology Development Strategy 2020-25. - Vision: \$1 Trillion bioeconomy by 2030 (EY-FICCI Report).
Skills & Workforce Development	<ul style="list-style-type: none"> - National Mandate: EO calls for growing a diverse workforce; NSF/DOE programs target STEM & bioprocessing. 	<ul style="list-style-type: none"> - Programs Embedded: Training integral to CSIRO FSP & ARC Centres - Commercial Training: Incubators like Bio10x (A\$140k/ startup). 	<ul style="list-style-type: none"> - KET Agenda: "Key Enabling Technologies" KIA explicitly drives skills development. 	<ul style="list-style-type: none"> - Centre-Led Training: iBioIC delivered 52 PhDs, 94 MScs (2012-2017), plus bespoke CPD. 	<ul style="list-style-type: none"> - Industry-Led Model: NIBRT provides cutting-edge training for biopharma manufacturing (global standard). 	<ul style="list-style-type: none"> - Scale-Driven: Massive output of STEM graduates; targeted training in strategic tech fields including bio. 	<ul style="list-style-type: none"> - "Bio-everything for everybody": BioE3 Strategy emphasizes inclusive skilling. - Strong IT-bio convergence focus.
Investment & Commercial Activity	<ul style="list-style-type: none"> - VC Market: World's largest, deepest VC/PE for biotech. Strategic Investment: DOD's Distributed Bioindustrial Mfg. Program (\$23M+ awarded). 	<ul style="list-style-type: none"> - VC Growth: Main Sequence Ventures (CSIRO-backed) key player. - Government Co Investment: MMI provides crucial project co-funding. 	<ul style="list-style-type: none"> - Public Co-Investment: Schemes via Netherlands Enterprise Agency (RVO). - Corporate VC: Active investment from chemical/food multinationals. 	<ul style="list-style-type: none"> - Sector Growth: Companies active increased from 43 (2012) to 147 (2020); turnover from £189M (2013) to £797M (2020). 	<ul style="list-style-type: none"> - FDI & Scaling: Strong FDI in pharma manufacturing; Enterprise Ireland supports start-ups. 	<ul style="list-style-type: none"> - Public Markets: STAR Market & HKEX fueled rise; biopharma innovation market cap: \$3B → \$380B (2016-2021). 	<ul style="list-style-type: none"> - Startup Surge: 1,300+ new biotech startups in 2021 alone (5,300+ total) - BIRAC Funding: Manages significant public venture funds.
Commercialisation & Economic Impact	<ul style="list-style-type: none"> - Global Leaders: Produces dominant firms in therapeutics & industrial biotech (e.g., synthetic biology unicorns). 	<ul style="list-style-type: none"> - Sector Strengths: Strong commercialisation in agriculture / food and mining biotech. - Progress: 16+ new synbio startups founded since 2021. 	<ul style="list-style-type: none"> - Industrial Leader: World-leading in scaling biobased chemicals & materials (e.g., bioplastics, advanced biofuels). 	<ul style="list-style-type: none"> - Exceeded Targets: Surpassed initial 2025 goals early; new "stretch targets" set in 2022 update. 	<ul style="list-style-type: none"> - Pharma Manufacturing Hub: Global leader in commercial-scale production of biologics, vaccines, and advanced therapies. 	<ul style="list-style-type: none"> - Scale & Speed: Rapid translation; now a major global supplier of vaccines, APIs, and bio-based products. 	<ul style="list-style-type: none"> - Affordable Innovation: Global hub for low-cost vaccines, biosimilars, and Agri-Bio solutions. - "Pharmacy of the World".



Stakeholder Engagement

Chapter 4: Stakeholder Engagement

This chapter presents the findings from two complementary strands of primary data collection: the semi-structured interviews and the online stakeholder survey. Together, these instruments gathered perspectives from across academia, industry, government, and the broader innovation ecosystem, providing the evidence base that informed the strategic roadmapping workshop and the final recommendations presented in this report.

4.1 Key Findings from Semi-Structured Interviews

Northern Ireland's Key Strengths and Current Capabilities

Interviewees identified a rich and varied set of existing strengths upon which an engineering biology strategy could be built:

- **Precision medicine and diagnostics cluster:** Multiple interviewees highlighted Northern Ireland's strength in precision medicine as a genuine competitive advantage, with one interviewee describing it as an "established NI strength" that nevertheless requires better connectivity to UK-wide catapult and hub infrastructure. The region hosts a university-based centre of excellence in precision medicine alongside major companies with global operations spanning companion diagnostics, biomarker development, and medical device manufacture. Interviewees consistently identified QUB, Ulster University, and companies including Almac, Randox and others as key actors in an integrated life sciences ecosystem, with several noting that this combination of university research and globally operating indigenous companies is unusual for a region of Northern Ireland's size. One industry leader described capabilities that extend from biomarker development through to clinical deployment in the UK, US, and China. Several interviewees further highlighted that the Windsor Framework's dual market access provides a distinctive commercial advantage for diagnostics and medical device companies based in Northern Ireland, enabling products developed in the region to meet both MHRA and EMA regulatory requirements simultaneously – a factor which, according to one interviewee, is actively attracting US companies seeking to access both markets through a single site.
- **Strong research base across two universities and a statutory research institute:** Interviewees consistently identified the research capabilities across Northern Ireland's two main universities and the Agri-Food and Biosciences Institute as the principal pillars of the region's engineering biology capability. One academic leader outlined strengths across all four application domains, identifying world-leading capabilities in antibody engineering, biocatalysis, bioprocessing, cell therapies, and biomaterials. Another highlighted diagnostic expertise "across the entire spectrum from environment to farm to fork to human health." The statutory research institute was recognised for its role spanning soil to sea and farm to fork, employing approximately 650 permanent staff.
- **Digital infrastructure and data capabilities:** Northern Ireland's electronic patient records system was consistently described as among the best in the UK. This digital infrastructure, combined with digital health and cybersecurity strengths and major data analytics investments through city and growth deals, creates a distinctive platform for data-driven engineering biology applications.

- **Windsor Framework and dual market access:** Northern Ireland's dual market access under the Windsor Framework was identified as a significant opportunity by several interviewees. One academic noted that "if a company runs a trial here, they can work with regulators in both Europe and UK – potentially FDA too." An industry leader confirmed that US companies are actively seeking NI partnerships specifically to access both MHRA and EMA regulatory pathways. However, another interviewee offered a counterpoint, noting that the Framework is "a benefit when you have a product to sell" but "not a benefit when you're developing a product," particularly for emerging SMEs.

Agri-food ecosystem: One government interviewee noted that Northern Ireland's agri-food sector produces protein output vastly exceeding the needs of its own population³⁷, creating both environmental challenges and engineering biology opportunities. A research institute representative highlighted that food production is proportionally much higher than in other parts of the UK, while an innovation infrastructure leader identified the extensive agricultural economy as a foundation for industrial biotechnology applications.

Advanced manufacturing transferable skills: One interviewee made a distinctive argument that Northern Ireland possesses a strong cross-sector engineering and manufacturing pedigree – including in aerospace, where the region hosts the only facility in the UK that can still design and test a complete aircraft wing and has produced Airbus's first European gold/silver-rated supplier – with engineering, manufacturing, planning, execution, and data management skills that could transfer directly to bioengineering challenges. Similarly, the materials handling sector (controlling a significant share of the global market) brings fabrication skills applicable to bio-manufacturing. Northern Ireland's aerospace supply chain holds six SC21 Gold awards – more than any other UK region – accounting for over 50% of the UK's Gold awards nationally³⁸. In 2025, Bangor-based Denroy became the first SME in Europe to achieve Silver status under the Aero Excellence International programme³⁹. Queen's University Belfast maintains a strategic research partnership with Rolls-Royce in engineering design, including the Re-Imagining Engineering Design (RIED) programme and the EPSRC-funded Digital Design Network Plus (D2N+) project.⁴⁰

Key Players and Organisations

Interviewees identified a consistent set of leading organisations across the ecosystem:

- **Academia:** Both universities were cited for research strengths across life sciences, engineering, computing, pharmacy, biological sciences, and food security. Key centres of excellence, industry-facing infrastructure hubs, and bioengineering prototyping capabilities were highlighted. The statutory research institute was recognised for its breadth of applied research across agriculture, veterinary, marine, and environmental sciences.
- **Industry:** A small number of major companies with global operations were consistently cited as anchors of the sector, spanning drug development, biocatalysis, peptide chemistry, diagnostics, veterinary pharmaceuticals, and antibody engineering. Emerging companies in cell therapies, next-generation diagnostics, and industrial biotechnology were also identified, alongside established multinationals with NI operations in medical devices.

37 Published DAERA data shows that the region's agricultural output meets the protein requirements of several times its population of 1.9 million – DAERA (2019). Estimated protein and dietary energy equivalents from Northern Ireland agricultural production (internal calculation, 2019 data). Reaffirmed by DAERA Chief Veterinary Officer in *agendaNI*, November 2025

38 ADS Group, *Northern Ireland Facts & Figures 2024* (Belfast: ADS Group, July 2024). Available at: <https://www.adsgroup.org.uk/knowledge/turnover-of-northern-irelands-aerospace-defence-security-and-space-sectors-doubles-to-2bn-exceeding-targets/> (Accessed 26 March 2026)

39 ADS Group, 'Northern Ireland's Denroy Becomes First Business to Achieve International Award at the Paris Airshow', 19 June 2025. Available at: <https://www.adsgroup.org.uk/knowledge/northern-irelands-denroy-becomes-first-business-to-achieve-international-award-at-the-paris-airshow/> (Accessed: 26 March 2026).

40 Queen's University Belfast, 'Queen's Leading £1.7m Project to Help Drive Forward Engineering', 2025. Available at: <https://www.qub.ac.uk/News/Allnews/2025/driving-forward-engineering.html> (Accessed: 26 March 2026).

- **Innovation infrastructure:** An advanced manufacturing innovation centre was identified as a potential Catapult associate or interim centre, alongside university commercialisation and incubator programmes. A life sciences coordination body was noted, though several interviewees emphasised that the absence of a dedicated life sciences Catapult or CPI presence in Northern Ireland represents a significant gap.
- **Government and support:** Key government departments responsible for economic policy, science strategy, and trade and investment were identified, alongside the Matrix Panel’s strategic advisory role and innovation support agencies. One policy interviewee highlighted the importance of bringing industry experts together through the Panel to identify areas of focus.

External Drivers and Emerging Trends

Interviewees identified a compelling convergence of drivers creating demand for engineering biology capabilities:

- **Environmental and sustainability pressures:** One industry leader placed environmental concerns “very high on the list,” noting customer-driven demands for CSR approaches, reduced emissions, minimised waste, and greener manufacturing. A government interviewee highlighted the Lough Neagh pollution crisis (blue-green algae threatening drinking water for a third of NI’s population) as a unique alignment of political priority and engineering biology opportunity. An academic connected environmental challenges directly to the NI Executive’s Programme for Government.
- **Ageing population and chronic disease:** One industry interviewee identified ageing population as the principal market driver, noting that “you can tell a story around life and health science purely using ageing population as the model.” This creates opportunities across diagnostics, preventive medicine, digital health monitoring, and clinical trials at home. An estimated 170,000 working-age people in NI are not working due to ill health, attracting widespread attention across government and academia, presenting both a health challenge and an economic opportunity.
- **UKRI funding landscape and national strategy:** A government interviewee described a radically changing UKRI research landscape with *three priority funding buckets*⁴¹ – curiosity-driven, public policy-led, and industrially relevant research. Engineering biology has been identified in the UK government’s Industrial Strategy as a frontier technology with the highest potential for growth. A policy interviewee noted that significant funding is being directed into engineering biology nationally, but NI “has not yet seen funding come its way – the hubs are going elsewhere.” This concern relates specifically to funding programmes branded under engineering biology – NI has attracted significant competitive UK funding in adjacent areas, notably through the Innovate UK Strength in Places-funded Future Medicines Institute (FMI), City and Growth Deals, and collaborative projects with bodies such as CPI.
- **Supply chain reshoring and sovereignty:** One industry interviewee described a post-COVID desire from clients and government to reshore from India and China due to supply chain concerns and regulatory issues. Interviewees highlighted supply chain fragility as a significant concern. One noted that NI’s dependence on imported goods – including food and laboratory consumables – leaves it acutely exposed to shipping disruptions, as demonstrated during COVID-19. Another flagged that consumables supply chains remain predominantly sourced from China, with an estimated 50% of consumables ending up in landfill, raising both resilience and sustainability concerns.

⁴¹ Review suggests a fourth one which is cross-cutting category supporting enabling infrastructure, talent, and international partnerships

- **AI and digital convergence:** Multiple interviewees identified AI as a transformative trend, highlighting digital twins for drug formulation, electronic health records creating new opportunities, AI-driven antibody development, and enzyme engineering using machine learning as key emerging capabilities. This also includes digital twins and digital biotech control systems.
- **Regulatory divergence as opportunity and constraint:** One interviewee stressed that Northern Ireland “still follows European rules” and “cannot grow any CRISPR-modified crops,” placing a major constraint on plant-based engineering biology. Conversely, another highlighted UK precision breeding legislation as enabling genetic modification up to the point feasible through conventional breeding, creating potential regulatory arbitrage opportunities.
- **Political alignment with engineering biology:** Several interviewees emphasised that many of the NI Executive’s Programme for Government priorities – cutting health waiting times, protecting Lough Neagh, providing affordable sustainable housing – can be directly addressed through engineering biology applications. One noted that “politics and technology can align” when political priorities and engineering biology solutions push in the same direction.

Most Promising Application Areas

Interviewees identified specific applications across each of the four priority sectors:

Healthcare and Medicine:

- **Advanced cell therapy:** One academic described CAR-based cell therapy as “the cutting edge,” using reprogrammed immune cells to change disease outcomes. A major all-island initiative with approximately €100 million in total funding was highlighted as a transformational programme moving cell therapy from oncology into autoimmunity and potentially neurodegeneration.
- **Precision medicine and companion diagnostics:** This was positioned as a long-standing strength with companies well-placed for the pharmaceutical industry’s shift towards personalised treatments. Diagnostic capabilities span both universities and multiple companies.
- **Antibody engineering and drug delivery:** Interviewees identified world-leading capabilities in antibody engineering with multiple molecules in clinical development, alongside antibody drug conjugates, oligonucleotide delivery systems, biomaterials for wound repair, and microneedle technologies.
- **Bacteriophage applications:** Bacteriophage-based approaches for both environmental remediation and antimicrobial applications were highlighted as an emerging area of expertise.

Agri-Food and Environment:

- **Rumen microbiome manipulation:** Northern Ireland was described as possessing considerable knowledge in manipulating the microbiome in the cow’s rumen to reduce methane, presenting a direct engineering biology contribution to Net Zero targets for the livestock sector.
- **Precision breeding:** This was identified as a key application area to improve agri-food competitiveness and address environmental side effects of increased agricultural productivity. One interviewee described NI’s food security research as “a short leap to synthetic biology.”
- **Biosensors and food traceability:** Biosensor development, synthetic antibody production without using animals, and reagent bioengineering for stability and safety were identified as distinctive NI capabilities spanning environmental monitoring through to food safety.

- **Bio-based packaging:** Northern Ireland has an established R&D pedigree in polymers and thin film development, including through AMIC and QUB. Interviewees identified an opportunity to build on this by applying microbial processes to produce bio-based packaging domestically, linking the region's food production strengths to its packaging capabilities within a broader bioeconomy framework.

Industrial Biotechnology:

- **Biocatalysis and enzyme engineering:** Collaboration between university researchers and major industry partners on biocatalysis for industrial bioprocessing was highlighted as a key strength. Novel enzymes for green economy applications – such as enzymes that can break down rubber – were identified as a potential niche where NI could develop a distinctive role.
- **Sustainable materials:** Natural resins that are recyclable and fibres such as hemp and flax for structural materials were highlighted, with NI having an opportunity to position itself as a UK lead in natural fibre composites. Opportunities in sustainable fuel development and anaerobic digestion that leverage existing engineering strengths were also identified.

Environmental Solutions:

- **Lough Neagh bioremediation:** Multiple interviewees identified the Lough Neagh environmental crisis as a distinctively Northern Ireland challenge where engineering biology solutions – including bacteriophage deployment, phosphorus removal, and bioremediation – could address a pressing local need with globally exportable innovations.
- **Novel biomaterials for construction:** The potential for concrete alternatives using algae-based materials was highlighted, linking environmental sustainability with construction industry innovation and addressing the Programme for Government priority of affordable, sustainable housing.

A more detailed analysis table of application areas is provided in Annex I, which highlights key researchers and groups in Northern Ireland, infrastructure and investments, as well as a few active companies.

Northern Ireland's Relative Positioning

Interviewees offered a nuanced assessment of Northern Ireland's competitive position:

- **Pockets of excellence but lacking critical mass:** One interviewee assessed NI as “very much lagging” with capabilities that are “potentially disadvantaged” relative to other regions. Another noted that none of Innovate UK's six national engineering biology hubs are led from NI, none of the relevant Catapults (Cell and Gene Therapy, Medicines Discovery, CPI) have a presence in NI, and NI received none of the 48 Innovate UK Engineering Biology Awards in 2024.
- **Window of opportunity:** A government interviewee argued that “the window of opportunity is now – even leading UK centres aren't that far ahead,” emphasising that NI's economy “cannot prosper without embracing engineering biology” and that it is possible to become a leader from a relatively low base since the industry is still emerging.
- **Gap between industry and academia in accessing national funding:** One industry interviewee described academia as quite good at securing Research Council finances, but industry as quite slow at engaging with Innovate UK, partly because local funding agencies provide an easier route. As someone with significant experience in the European funding arena, one interviewee saw academia behind UK averages and industry a whole step further back.

- **Unique all-island potential:** Several interviewees noted that the Republic of Ireland has focused on attracting multinational manufacturing, whilst NI has successfully scaled indigenous companies – creating a complementary dynamic. Multiple interviewees argued for greater all-island collaborations leveraging research strengths in the north and manufacturing/pharma scale in the south. Some recent examples include the Cross-border Eastern Corridor for Medical Engineering and the new Health Frontiers – Technology Innovation Centre.
- **Brain drains as evidence of untapped capacity:** One academic made the distinctive argument that the loss of life sciences graduates to the Republic of Ireland actually demonstrates existing capacity for growth: “We’re not at maximum employment like Treasury assumes...” If sufficient jobs were created, the talent pipeline already exists.
- **Public attitudes as an asset:** A government interviewee cited the Public Attitudes to Science Survey showing that NI is more accepting of technologies such as machine learning and autonomous vehicles than the rest of the UK, describing a greater tolerance for innovation driven by economic need.

Infrastructure and Skills Gaps

Infrastructure:

- **No life sciences catapult or hub:** Multiple interviewees emphasised that Northern Ireland lacks any Catapult presence, making it difficult to connect with the UK’s national innovation infrastructure. One interviewee who had previously led a UK Catapult noted that “we had intentions of setting a toehold in Northern Ireland but it hasn’t happened.” Another described the region’s advanced manufacturing centre as potentially filling this gap as an associate or interim Catapult centre.
- **Scale-up and translation facilities:** One interviewee stated that “any kind of scale-up is very difficult in Northern Ireland,” with stakeholders needing to access bioeconomy campuses in Ireland, CPI, or facilities in continental Europe. Others highlighted the lack of immediate regional access to specialist equipment, and the absence of local capacity for primer, antibody, or recombinant protein production – all of which must be imported. It was further suggested that the priority is not necessarily establishing a standalone Catapult centre in NI, but rather developing regional scale-up facilities with formal linkages to existing UK Catapult centres such as CPI, the Cell and Gene Therapy Catapult, and the HVM Catapult network.
- **Cell therapy infrastructure:** Reactivation of the cell pharmacy at Northern Ireland’s main teaching hospital was identified as essential for receiving and administering cell therapies to patients, alongside facilities to reprogram cells locally rather than sending them to centres in Great Britain or the Republic of Ireland.
- **Basic utilities constraints:** One interviewee raised the practical concern that energy is expensive, getting good connections is difficult, and water infrastructure is problematic: “If you’re looking at creating new manufacturing plants at scale, you need to address utilities early.”

Skills:

- **Clinical academic shortage:** One interviewee described this as a critical gap, noting that NI is “well below UK proportional number of clinical academics” with approximately one third aged 55+, meaning significant expertise will be lost within a decade. NHS-funded training is focused on waiting list reduction rather than research capacity building.
- **Industry-readiness gap:** An industry interviewee described graduates often lacking practical laboratory skills and soft skills such as teamwork and project management, partly attributable to COVID-era online teaching and university cost pressures reducing laboratory work. It was noted that companies are attempting to support the addressing of these challenges through guest lectures, project supervision, and course development support.
- **Grant-writing and bid quality:** Multiple interviewees identified poor bid quality as a systemic weakness, emphasising the need to understand Green Book and Aqua Book requirements. One noted that “grant writing skills are lacking – if you don’t know how to write Innovate UK grants, you can’t get the funding.”
- **Entrepreneurial culture and commercialisation:** While NI universities have demonstrated strong entrepreneurial activity – with Queen’s ranked highly for spin-out creation per head – interviewees identified structural barriers to commercialisation, including university equity stakes, valuations, and access to follow-on funding. One interviewee contrasted Northern Ireland with leading UK universities where students receive entrepreneurial training throughout their degrees, though others noted that spin-out culture has increased significantly in recent years. The absence of sufficient academics with industry experience who can mentor students through the commercialisation process was noted as a further gap⁴².
- **Regulatory expertise:** Regulatory expertise was described as siloed, with major companies maintaining internal regulatory departments, but the broader regional ecosystem lacked this capability and required external consultants.

Barriers and Challenges

Interviewees identified a layered set of barriers constraining the sector’s development:

- **Valley of death in commercialisation:** One interviewee described a systemic catch-22: “No shared innovation space to develop manufacturing methods, no ecosystem of manufacturers in North or South. Every individual opportunity becomes a dead end. They either get licensed to the States, move to England, or stay as just research.” Another corroborated this, highlighting the gap between TRL 4 - 6 as the critical missing link. The severity of this challenge varies by domain – AMIC, for example, has facilities to support scale-up in clean technology and biopolymers – but accessing scaling capital remains a cross-cutting barrier that can draw early-stage businesses to England or the US to secure funding.
- **Fragmented strategic coordination:** An industry leader argued for an office bridging health and economy departments, noting that “currently there is no joined-up approach – academia, healthcare, and industry are not really following common strategy.” An existing sector coordination body was described as doing its best but “not funded enough or empowered to set regional strategy.”
- **Accountability and follow-through:** One interviewee noted that the question of “who is accountable” is where previous initiatives have consistently failed: “Been around 20 years of reports; recommendations don’t get funded or taken forward, it ends up in another workshop and fades out.” A policy interviewee acknowledged that “we do lots of really good research, and sometimes it sits on the shelf.”

⁴² Challenges are compounded by structural barriers to university spin-out formation – including equity stakes, valuations, and IP terms – as highlighted by Tracey Review [Tracey, I. and Williamson, A., *Independent Review of University Spin-out Companies* (London: HM Treasury and Department for Science, Innovation and Technology, November 2023). Available at: <https://www.gov.uk/government/publications/independent-review-of-university-spin-out-companies> (Accessed: 26 March 2026).]

- **Windsor Framework regulatory constraints:** One interviewee noted that NI could grow CRISPR crops with a special derogation, “but that’s an extra obstacle.” University researchers at bench-scale do not encounter these barriers, but research institutes working at TRL 4–6 face them directly. The dual regulatory burden adds cost and complexity for emerging SMEs.
- **Venture capital access:** One interviewee described startups struggling to access VC funding, noting that VCs may require companies to relocate closer to investor bases. Another identified a similar concern regarding the absence of repeat founders and investment expertise within NI’s engineering biology ecosystem.
- **Geopolitical uncertainty:** One interviewee highlighted challenges arising from the US administration’s trade policies as a significant concern, noting that new pharmaceutical manufacturing facilities may increasingly be built in the US rather than Europe, with a risk of the wider European pharma sector retrenching. Uncertainty around trade and regulatory alignment was described as a major barrier to progress – “any recommendations require both government and private sector investment, and the private sector won’t invest in uncertainty.”

The Role of Collaboration

Every interviewee emphasised collaboration as essential, with several distinctive perspectives emerging:

- **All-island collaboration:** One academic described a major all-island research initiative as a model, noting that “the island should be seen as a set of research campuses” where researchers go to whichever site does the highest quality work. An industry leader noted that international companies already see North and South Ireland as a single ecosystem.
- **Cross-sector fertilisation:** One interviewee argued that “interesting research and knowledge comes from two distinct fields working together – it’s at that intersection, often discovering things you weren’t looking for.” Another drew an extended parallel with Sheffield’s Advanced Manufacturing Research Centre, describing how that region’s transformation from mining and steel to a world-leading innovation district happened “in a generation – 20–25 years” through deep technical strengths combined with strong industry relationships.
- **UK national network integration:** One interviewee stressed the need for formal mechanisms to connect NI to the national innovation infrastructure, particularly the Catapult network. Another emphasised cross-fertilisation across the academic, industrial, and political communities, warning that simply injecting money will fund disparate areas without creating community.
- **Diaspora engagement:** One interviewee highlighted a substantial expats network of Northern Ireland professionals within international pharmaceutical and life sciences companies, suggesting that a structured diaspora engagement programme could harness this untapped resource for mentoring, strategic advisory support, and connectivity to global industry networks.

Top Strategic Priorities

When asked to identify their top three priorities for policy, funding, or strategic action, interviewees converged on several recurring themes:

- **Strategic coordination and leadership:** One interviewee called for an office for life and health sciences with cross-jurisdictional authority reporting at the highest political level, with both authority and budget to drive change. Another argued for a single person with convening authority rather than another committee. A third cautioned against creating “another committee or champion” and urged focus on solving real problems such as Lough Neagh.

- **Shared innovation infrastructure:** One interviewee's top priority was securing funding for shared manufacturing facilities enabling life sciences companies to start manufacturing collaboratively. Another called for a life sciences Catapult presence in NI, while a third advocated for adding biological capabilities to existing advanced manufacturing infrastructure.
- **National funding competitiveness:** One industry interviewee prioritised tapping into UKRI ring-fenced engineering biology funding and Horizon Europe, and de-mystifying the application process for industry. A government interviewee stressed the need to build bid quality that meets Treasury requirements (Green Book/Aqua Book) to secure national investment.
- **Skills and culture:** One interviewee argued for focusing on "culture, training, entrepreneurship rather than just new buildings," including grants, programmes, and Catapult connections. Another advocated for an industry-readiness programme modelled on the successful Fit4Nuclear approach – proactively engaging companies to assess their existing capabilities against engineering biology opportunities and providing targeted support to bridge identified gaps.
- **Collaboration and outward-looking approach:** One academic's overarching priority was "collaboration and connectedness – look outwards as much as possible and collaborate for internal benefit," emphasising that this should come strongly through any strategy. An industry interviewee called for better connecting what NI already has, recognising existing strengths rather than producing another report calling for a large new building.

Vision for the Future

Interviewees articulated a range of visions for Northern Ireland's engineering biology future:

- Engineering biology as "a core driver of the economy," with the argument that NI's economy "is going to have to reinvent itself in the next two decades" and the missing piece being "entrepreneurs and centres to help them succeed."
- A regional focus on synthetic biology driving transformation in how NI does science and engineering, creating a community with underlying knowledge of genetic manipulation technologies.
- "A sense of who we are as a sector" with more voice, better sharing of resources and knowledge, whilst avoiding trying to be all things to all people.
- A centre of excellence bridging both universities with industry partners and government bodies, with business-needs-driven research and clear commercialisation pathways.
- Demonstrating ingredients for success within specific sub-themes, supported by case studies and clear identification of gaps and actions needed to move from current state to future state.

4.2 Key Findings from Stakeholder Survey

Current Landscape and Strengths

- **Strong research base across two universities and AFBI:** Respondents consistently identified the two universities and AFBI as the principal pillars of NI's engineering biology capability, citing world-class expertise in synthetic biology, microbiology, biosensors, food security, animal genetics, and biomedical engineering.
- **Established industry strengths:** Major pharmaceutical, diagnostics, and veterinary companies were repeatedly cited, with strengths in biotechnology, fermentation, enzyme engineering, and biomaterials manufacture.

- **Agri-food ecosystem:** NI's agri-food system was viewed as an excellent foundation for engineering biology, including processing, agri-engineering, and R&D capability in animal welfare, food quality, and environmental science.
- **Connected ecosystem:** NI's compact size was noted as enabling strong interconnections between industry, academia, and government.
- **Capability gaps:** Respondents flagged a lack of dedicated engineering biology centres, limited scale-up infrastructure, insufficient GMP/CMO facilities, no local DNA/RNA synthesis capability, absence of a life sciences Catapult, limited venture capital access, and a workforce below critical mass.

Trends and Drivers

- **Sustainability and Net Zero:** The most frequently cited driver, encompassing corporate sustainability targets, greener manufacturing, reduced agricultural emissions, and bio-based alternatives.
- **Climate change:** Impact on agriculture, crop production, water quality, and the growing need for bioremediation and monitoring solutions.
- **Food security and supply chains:** NI's vulnerability to supply chain disruptions and the need for domestic production capacity and alternative protein sources.
- **Antimicrobial resistance:** A growing challenge requiring new diagnostic tools, vectored vaccines, bacteriophage-based treatments, and biosensor technologies.
- **AI and computational biology:** AI-enabled biological design, machine learning, bioinformatics, and digital twins as transformative trends.
- **Policy and regulatory landscape:** The Windsor Framework is both an opportunity (dual market access) and a constraint (regulatory complexity). UK strategies identify engineering biology as a frontier technology, but NI has yet to capture significant national funding.

Most Promising Applications

Short-term (next 2 years):

- **Healthcare:** AMR solutions, RNA therapeutics manufacturing, drug discovery, diagnostics and biosensors, MedTech devices, vaccines and antibody engineering, gene therapy.
- **Agri-food:** Methane-reducing feed additives, ammonia mitigation, biofertilisers, alternative protein for animal feed, fermentation ingredients, food safety and traceability, soil solutions.
- **Environmental:** Nutrient extraction from agricultural waste, bioengineered lactic ferments from locally isolated microorganisms.

Medium-term (3–5 years):

- **Healthcare:** Vaccine development, cell and gene therapy, personalised medicine, AI-driven enzyme solutions for decarbonisation.
- **Agri-food:** Novel antimicrobials, breeding advances, precision-fermented foods, engineered dairy cultures, low-emission livestock systems, advanced bioprocessing.
- **Environmental and industrial:** Bioenergy, biomethane, biopolymers, fuels, microbial biointraants, GM agricultural applications (subject to regulatory change).

Longer-term (5–10 years):

- **Transformational capabilities:** Disease-resistant gene-edited livestock and crops, commercial wet-lab infrastructure, synthetic biology platforms, new agri-bio supply chains and export products.

Niche Opportunities

- **Biocatalysis and enzyme engineering:** Real-world applications for sustainability, biofuels, and biomaterials through AI and metagenomics.
- **Diagnostics with digital health records:** Full value chain from biosensor development to clinical deployment, leveraging NI's excellent electronic patient records.
- **Animal science and grassland production:** World-leading research in animal genetics, rumen microbiome, and ryegrass breeding.
- **Agri-tech and biosensor hub:** Integrating engineered biology with digital agri-tech and supply-chain traceability.
- **Microbial biotechnology:** Development of a Northern Ireland microbial culture collection, bioinfrants sector, and exploitation of untapped microbial biodiversity.

Skills and Infrastructure Needs

- **Cross-disciplinary training:** Bioprocessing, synthetic biology, bioinformatics, AI, data science, computational biology, and regulatory knowledge.
- **Entrepreneurial skills:** A shortage of individuals combining technical and business acumen.
- **Scale-up facilities:** Pilot-scale biomanufacturing, GMP contract manufacturing⁴³, and shared equipment to bridge the valley of death.
- **Centralised capabilities:** Shared data centres, sequencing hubs in NI, and centralised bioinformatics facilities.
- **Investment landscape:** Better VC access, scaling support, and integration with UK and Republic of Ireland networks.

Barriers and Strategic Priorities

Principal barriers:

- **Funding:** Insufficient public and private investment, lack of UKRI PhD funding for NI, poor investor landscape.
- **Infrastructure:** Fragmented scale-up facilities, no Catapult, limited pilot and translation infrastructure.
- **Skills:** Shortage of multidisciplinary talent, insufficient expert concentration, brain drain, limited entrepreneurial culture.
- **Regulation:** Windsor Framework constraints, dual-regulatory complexity, slower imports.
- **Coordination:** No clear engineering biology strategy, fragmented departmental coordination, UK TechBio capability concentrated elsewhere.
- **Public perception:** Concerns about acceptance of genetic modification and synthetic biology.

⁴³ It was noted during review that GMP facilities are prohibitively expensive for the NI ecosystem.

Top strategic priorities:

- **Shared biomanufacturing infrastructure:** An affordable, early-stage R&D and pilot-scale manufacturing facility accessible to SMEs, with formal pathways into CPI and other UK Catapult centres for later-stage scale-up.
- **Coherent NI strategy:** Aligned with UK strategies but tailored to NI strengths, with clear accountability.
- **Talent and skills investment:** Incentives to attract researchers, leadership programmes, and better education-industry connectivity.
- **Ecosystem coordination:** Coherent offer across academia, healthcare, and industry, tapping into UK and Republic of Ireland networks.
- **Ring-fenced collaborative funding:** Large-scale cross-sector funding for a cluster of excellence, not smaller dispersed grants.

Vision for 2035

- A globally recognised, self-sustaining engineering biology hub with strong industrial, academic, regulatory, and workforce foundations.
- A globally competitive, commercially impactful, and environmentally transformative presence in agri-food engineering biology.
- Leadership in biomaterials, RNA therapeutics, and cancer vaccines, alongside a vibrant home-grown sector.
- Successful spin-outs and SMEs, internationally recognised research, and circular waste-to-value processes.
- An NI ecosystem driving science excellence for societal benefit across key challenge areas.



Strategic Landscape Analysis

Chapter 5: Strategic Landscape Analysis

5.1 Why Layer: Trends and Drivers

The Why layer captures the external drivers, trends and forces shaping the environment for engineering biology in Northern Ireland. 421 statements were clustered into 20 pre-workshop thematic groups across four sub-layers: Market Drivers, Policy and Regulations, Social, Technology and Environment, and Competitive Context. During the workshop, five new clusters were added, and all clusters were prioritised through voting. The strongest signals centred on climate change impacts (11 votes), funding access and industry-academia collaboration gaps (11 votes), skills deficit and fragmented leadership (11 votes), and UK industrial policy alignment (9 votes, new cluster). Table 5 and the first table in Annex II presents the full cluster inventory for this layer.

5.2 What Layer: Applications, Capabilities, Products and Services

The What layer identifies the specific applications, products and services where engineering biology can create value for Northern Ireland. 381 statements were clustered into 29 pre-workshop thematic groups across four sector-based sub-layers: Healthcare and Medicine, Agri-Food and Environment, Industrial Biotechnology, and Environmental Solutions. During the workshop, participants added a new cross-cutting sub-layer (B5), with five additional clusters. The circular bioeconomy received the highest number of votes (13) of any cluster in the What layer, followed by food security and the world-class agri-food research ecosystem (10 votes each). The integrated life sciences ecosystem (9 votes), the missing CPI-type bioengineering facility (9 votes), biocatalysis and enzyme engineering (9 votes), and the agricultural-tech sector disconnect (9 votes) also featured prominently. The second table in Annex II presents the full cluster inventory. Table 6 shows the landscape for this layer.

5.3 How Layer: Resources, Technologies and Enablers

The How layer assesses the resources, technologies, infrastructure and enabling conditions required to deliver on the opportunities identified in the What layer. 465 statements were clustered into 30 thematic groups across six sub-layers: Technology Platforms, Research Infrastructure, Skills and Education, Funding and Investment, Support Ecosystem, and Enabling Collaborations. The How layer was pre-populated from the literature review, interviews and survey, but was not subject to the same workshop voting, as the Why and What layers, reflecting the workshop's focus on prioritising external drivers and application opportunities before addressing resource requirements. The most heavily evidenced themes were coordination gaps and barriers (27 statements), European support infrastructure (27 statements), national research centres (25 statements) and strategic technology priorities (23 statements). See the Table 7 and the third table in Annex II for the cluster inventory for this layer.

5.4 Workshop Prioritisation

The strategic landscape analysis reveals a rich but fragmented ecosystem with significant strengths, clear gaps and compelling opportunities. The workshop prioritisation process identified the highest-priority themes across the Why and What layers, presented in Table 8.

The convergence of the highest-priority themes points to a clear strategic narrative: Northern Ireland possesses genuine research strengths in life sciences and agri-food, but is constrained

by inadequate scale-up infrastructure, fragmented coordination and insufficient connection to national funding and innovation networks. The circular bioeconomy emerged as the single most compelling cross-cutting opportunity, whilst biocatalysis and enzyme engineering were identified as potentially the region’s most distinctive technical capability. These priorities informed the topic roadmaps and recommendations developed in the subsequent chapters of this report.

Table 5: Landscape - Trends and Drivers

LAYER A	Short Term 2026-2027	Medium Term 2028-2030	Long Term 2031-2035
Market Drivers (Economic & Strategic)	A1.1 Global bioeconomy markets reaching \$2.2 trillion by 2040 with accelerating corporate investment		
	A1.2 Healthcare markets expanding for personalised therapeutics, cell therapies, and precision diagnostics		
	A1.3 Corporate sustainability targets and supply chain resilience driving demand for bio-based solutions		
	A1.4 Falling technology costs and AI integration lowering barriers to market entry		
	A1.5 City Deals and Windsor Framework to capture value from its life sciences base		
	Agri-food sector economic significance		
Policy & Regulations	A2.1 Regulatory complexity and EU-UK divergence creating both compliance burdens and innovation opportunities		
	A2.2 Windsor Framework dual market access remains under-exploited despite strategic potential		
	A2.3 Net zero legislation and climate targets compelling adoption of engineering biology solutions		
	UK industrial policy and strategic alignment		
	A2.4 Fragmented governance and geopolitical shifts require coordinated cross-departmental leadership		
	Regulatory framework evolution		
Social, Technology & Environment	A3.1 AI and digital technologies accelerating R&D and enabling precision biology applications		
	A3.2 Climate change impacts on agriculture, health and water driving demand for biological solutions		
	A3.3 Food security and supply chain resilience demanding domestic manufacturing capability		
	A3.4 Antimicrobial resistance and One Health creating cross-sector intervention opportunities		
	A3.5 Public perception and biosecurity concerns requiring trust-building and responsible innovation		
	A3.6 Brain drain and skills gaps constraining sector growth despite strong societal need alignment		
Competitive Context	A4.1 UK biotech research leadership but scale-up gap threatens international competitiveness		
	A4.2 Precision medicine and diagnostics as established NI strengths needing better coordination		
	A4.3 Windsor Framework dual market access creating unique regulatory and commercial advantage		
	A4.4 Funding access and industry-academia collaboration lagging behind other UK regions		
	A4.5 Skills deficit, brain drain and fragmented leadership constraining competitiveness		
	Grants and funding landscape evolution		

Table 6: Landscape - Applications, Capabilities, Products and Services

LAYER B	Short Term 2026-2027	Medium Term 2028-2030	Long Term 2031-2035
Healthcare & Medicine	B1.1 Cell and gene therapy expanding beyond oncology requiring local treatment capacity		
	B1.2 Precision medicine as established NI strength requiring hub/catapult connectivity		
	B1.3 AI-driven drug discovery and digital health platforms accelerating development		
	B1.4 Diagnostics and biosensors requiring domestic manufacturing capability restoration		
	B1.5 mRNA therapeutics and biomanufacturing scale-up leveraging CDMO capabilities		
		B1.6 Microbiome therapeutics and antimicrobials addressing resistance challenges	
		B1.7 Clinical academic capacity gap constraining research leadership and trials	
	B1.8 Strategic specialisation needed to differentiate from established UK centres		
	B1.9 Mental health pharmaceuticals and healthy ageing as emerging growth areas		
	B1.10 QUB, UU, Almac and Randox anchoring integrated life sciences ecosystem		
One Health approach: cross-sector integration			
Endemic disease: diagnostics and interventions			
			Collaboration: Future Medicine Institute
Agri-Food & Environment		B2.1 Precision breeding and gene editing for crop resilience and competitiveness	
		B2.2 Livestock genetics and animal engineering for disease resistance and emissions	
		B2.3 Methane reduction and low-emissions livestock through microbiome manipulation	
		B2.4 Fermentation technologies for alternative proteins and biomaterials	
	B2.5 Food security and supply chain resilience requiring local production capability		
		B2.6 Vertical farming and controlled environment agriculture on brownfield sites	
	B2.7 Agricultural-tech sector disconnect requiring better innovation policy alignment		
	B2.8 AFBI and universities anchoring world-class agri-food research ecosystem		
Healthcare-medicine-farm animal health convergence			
Industrial Biotechnology	B3.1 Missing CPI-type bioengineering facility limiting scale-up and catapult connectivity		
	B3.2 Lost manufacturing capability for antibodies, primers and recombinant proteins		
	B3.3 Domestic biomanufacturing for pandemic preparedness and supply chain security		
		B3.4 Biocatalysis and enzyme engineering for sustainable pharmaceutical manufacturing	
		B3.5 Bio-based materials and sustainable aviation fuels for decarbonisation	
	B3.6 Shared manufacturing facility enabling valley-of-death crossing for SMEs		
	AMIC labs incubate sensor manufacturing capabilities		
Environmental Solutions		B4.1 Bioremediation and water quality solutions addressing Lough Neagh challenges	
		B4.2 Circular bioeconomy replacing fossil feedstocks with bio-based materials	
	B4.3 Biofuels and green biorefineries for decarbonisation and net zero targets		
		B4.4 Carbon capture through biogenic CO ₂ sequestration from biomass processes	
		B4.5 Engineered microbial biofertilizers and ammonia emission reduction	

Table 7: Landscape – Resources, Technologies and Enablers

LAYER C	Short Term 2026-2027	Medium Term 2028-2030	Long Term 2031-2035
Technology Platforms	C1.1 Biofoundries & Automation: Automated Design-Build-Test-Learn infrastructure		
		C1.2 Biomanufacturing Platforms: Scale-up and production infrastructure C1.3 Regional Infrastructure Gaps: Critical missing capabilities requiring investment C1.4 Cross-Border Technology Access: All-island and UK-wide technology sharing	
	C1.5 Strategic Technology Priorities: Stakeholder-identified priority investments for NI		
Research Infrastructure		C2.1 National Research Centres: Major research centre models and investments	
	C2.2 NI Regional Facilities: Existing and planned infrastructure in Northern Ireland C2.3 Infrastructure Gaps: Missing capabilities limiting NI competitiveness		C2.4 Shared Facilities Model: Stakeholder priorities for collaborative infrastructure development
		C2.5 Systemic Infrastructure Challenges: Barriers to infrastructure development	
Skills & Education		C3.1 Formal Training Programmes: Established education and training infrastructure	
	C3.2 Critical Skills Gaps: Priority shortage areas requiring intervention C3.3 Strategic Skills Priorities: Stakeholder-identified priority competencies		
		C3.4 Workforce Development Challenges: Structural barriers to talent pipeline C3.5 Public Engagement & Awareness: Building understanding and acceptance	
Funding & Investment	C4.1 Grant Programmes & Public Funding: Established funding mechanisms C4.2 Strategic National Investments: Large-scale government investment programmes		
		C4.3 Valley of Death Challenges: TRL 4-6 funding gaps and commercialisation barriers	
	C4.4 Cross-Border Funding Opportunities: All-island and European funding access		
		C4.5 Strategic Funding Priorities: Stakeholder-identified investment needs C4.6 Private Investment Landscape: Venture capital and private sector dynamics	
Support Ecosystem			C5.1 European Support Infrastructure: EU-level support mechanisms and networks C5.2 US Support Programmes: American funding and support models
	C5.3 UK Regulatory Innovation: Regulatory frameworks supporting engineering biology		
	C5.4 Regional Support Entities: NI-specific support infrastructure		
		C5.5 Ecosystem Development Needs: Stakeholder priorities for ecosystem strengthening	
Enabling Collaborations	C6.1 International Collaboration Frameworks: Global governance and partnerships		
		C6.2 All-Island Collaboration Models: North-South partnership opportunities C6.3 Coordination Gaps & Barriers: Structural challenges to effective collaboration	
	C6.4 Strategic Collaboration Priorities: Stakeholder-identified partnership opportunities		

Table 8: Priority clusters for Trends & Drivers and Applications, Capabilities, Products & Services

A-Trends and Drivers	VOTES	%
A3.2: Climate change impacts on agriculture, health and water driving demand for biological solutions (MT)	11	9%
A4.4: Funding access and industry-academia collaboration lagging behind other UK regions (MT)	11	9%
A4.5: Skills deficit, brain drain and fragmented leadership constraining competitiveness (MT)	11	9%
A5.1: UK Industrial Policy and Strategic Alignment	9	7%
A1.2: Healthcare markets expanding for personalised therapeutics, cell therapies, and precision diagnostics (MT)	8	6%
A3.3: Food security and supply chain resilience demanding domestic manufacturing capability (MT)	8	6%
A2.2: Windsor Framework dual market access remains under-exploited despite strategic potential (MT)	7	6%
A4.2: Precision medicine and diagnostics as established NI strengths needing better coordination (MT)	6	5%
A5.2: Agri Fod Sector Economic Significance	6	5%
A5.3: Grants and Funding	6	5%
A1.5: City Deals and Windsor Framework to capture value from its life sciences base (MT)	5	4%
A2.3: Net zero legislation and climate targets compelling adoption of engineering biology solutions (MT)	5	4%
A5.4: Regulatory	5	4%
A1.4: Falling technology costs and AI integration lowering barriers to market entry (LT)	4	3%
A3.1: AI and digital technologies accelerating R&D and enabling precision biology applications (MT)	4	3%
A3.4: Antimicrobial resistance and One Health creating cross-sector intervention opportunities (MT)	4	3%
A5.5: Clean Energy	4	3%
A1.1: Global bioeconomy markets reaching \$2.2 trillion by 2040 with accelerating corporate investment (MT)	3	2%
A2.1: Regulatory complexity and EU-UK divergence creating both compliance burdens and innovation opportunities (MT)	3	2%
A4.1: UK biotech research leadership but scale-up gap threatens international competitiveness (ST)	3	2%
A2.4: Fragmented governance and geopolitical shifts require coordinated cross-departmental leadership (MT)	2	2%
B5.3: Endemic Disease - Diagnostics and Interventions	1	1%

B-Applications, Capabilities, Products & Services	Votes	%
B4.2: Circular bioeconomy replacing fossil feedstocks with bio-based materials (MT)	13	9%
B2.5: Food security and supply chain resilience requiring local production capability (MT)	10	7%
B2.8: AFBI and universities anchoring world-class agri-food research ecosystem (LT)	10	7%
B1.10: QUB, UU, Almac and Randox anchoring integrated life sciences ecosystem (LT)	9	6%
B2.7: Agricultural-tech sector disconnect requiring better innovation policy alignment (MT)	9	6%
B3.1: Missing CPI-type bioengineering facility limiting scale-up and catapult connectivity (MT)	9	6%
B3.4: Biocatalysis and enzyme engineering for sustainable pharmaceutical manufacturing (MT)	9	6%
B3.3: Domestic biomanufacturing for pandemic preparedness and supply chain security (MT)	7	5%
B4.1: Bioremediation and water quality solutions addressing Lough Neagh challenges (MT)	7	5%
B1.4: Diagnostics and biosensors requiring domestic manufacturing capability restoration (MT)	6	4%
B2.4: Fermentation technologies for alternative proteins and biomaterials (MT)	6	4%
B5.2: One health Approach Cross Sector	5	4%
B1.5: mRNA therapeutics and biomanufacturing scale-up leveraging CDMO capabilities (LT)	4	3%
B3.6: Shared manufacturing facility enabling valley-of-death crossing for SMEs (MT)	4	3%
B1.3: AI-driven drug discovery and digital health platforms accelerating development (MT)	3	2%
B2.1: Precision breeding and gene editing for crop resilience and competitiveness (MT)	3	2%
B2.3: Methane reduction and low-emissions livestock through microbiome manipulation (LT)	3	2%
B3.5: Bio-based materials and sustainable aviation fuels for decarbonisation (MT)	3	2%
B4.3: Biofuels and green biorefineries for decarbonisation and net zero targets (ST)	3	2%
B4.5: Engineered microbial biofertilizers and ammonia emission reduction (LT)	3	2%
B5.4: Collaboration Future Medicine Institute	3	2%
B1.6: Microbiome therapeutics and antimicrobials addressing resistance challenges (LT)	2	1%
B4.4: Carbon capture through biogenic CO2 sequestration from biomass processes (LT)	2	1%
B5.5 AMIC Labs incubate sensor manufacturing capabilities	2	1%
B1.2: Precision medicine as established NI strength requiring hub/catapult connectivity (MT)	1	1%
B1.7: Clinical academic capacity gap constraining research leadership and trials (MT)	1	1%
B2.2: Livestock genetics and animal engineering for disease resistance and emissions (LT)	1	1%
B2.6: Vertical farming and controlled environment agriculture on brownfield sites (MT)	1	1%
B3.2: Lost manufacturing capability for antibodies, primers and recombinant proteins (MT)	1	1%
B5.1: Healthcare Medicine Farm Animal Health	1	1%
B5.3: Endemic Disease - Diagnostics and Interventions	1	1%



Topic Roadmap and Cases

Chapter 6: Topic Roadmaps and Cases

Through a structured process of prioritisation and group investigation, participants identified six key topic areas with the greatest potential for transforming Northern Ireland's engineering biology landscape. These priority topics were selected based on their alignment with regional strengths, the urgency of the challenges they address, and their feasibility within Northern Ireland's institutional and economic context. Each topic was explored by dedicated working groups who examined strategic context, scope, development pathways, required actions, key enablers, and barriers to success. The resulting topic roadmaps, presented in this chapter as case studies, represent the distilled insights and recommendations of researchers, industry leaders, policymakers, and support organisations working collectively to chart a course for engineering biology development in the region. Workshop summaries of the topic roadmap are given in Annex III.

6.1 Case Study 1: Food Security and Resilience

Summary

This initiative aims to ensure access to safe and nutritious food, produced while promoting environmental and economic stability through engineering biology. The focus is on developing food systems resilient to climate change and political challenges, and promoting human and planetary health by leveraging Northern Ireland's strong food sector.

Strategic Context and Case for Development

Northern Ireland's food sector is substantial, valued at £8 billion and employing 110,000 people, with 80% of production exported globally. The sector must respond to major global challenges, including climate change, food security, and sustainability. This initiative aligns strongly with the One Health framework, recognising the interconnection between human health, animal health, and environmental health.

Queen's University Belfast ranks number one for research excellence in food security, and Northern Ireland possesses significant expertise due to its concentrated scale. The sector's size and export orientation create both opportunity and vulnerability, necessitating innovation to maintain competitiveness while addressing sustainability challenges.

Scope of Engineering Biology Applications

Within Scope

Plants of the Future: The initiative encompasses accelerated plant breeding using engineering biology tools to develop crops better suited to changing climate conditions and with improved nutritional profiles.

Animals of the Future: Focus includes breeding low greenhouse gas-emitting animals and developing feeding innovations that reduce environmental impact while maintaining productivity.

Biobased Solutions: Engineering biology approaches to improve soil health and water quality, addressing critical environmental challenges facing agriculture.

Cross-Cutting Technologies: Microbiomes research and technologies such as CRISPR and Cas9 gene editing systems that can be applied across multiple domains.

Outside Scope

Non-biobased technologies are excluded from the core initiative, though some may be needed for scaling up biobased solutions.

Development Pathway and Timeline

Short-Term (1-3 Years)

Immediate priorities focus on mapping current expertise in engineering biology across Northern Ireland to identify capabilities and gaps. Critical infrastructure needs must be addressed, particularly plant growth facilities and fermentation capacity for scaling up innovations. Investment in people is paramount, both growing local talent and attracting international expertise.

The short term requires establishing cross-fertilization between institutes and building a larger cluster around the NI Diamond (the triple helix model connecting government, industry, and academia focused on food systems). Key policy drivers include UK-EU regulatory divergence and the emerging biomanufacturing sector.

Medium-Term (4-6 Years)

The medium term emphasizes capability development to address Technology Readiness Level (TRL) 3-4 gaps, where innovation often stalls between early research (TRL 1-3) and commercial scale-up (TRL 6+). Policy focus shifts to climate change adaptation and net zero targets, requiring coordinated efforts from both Department for the Economy (DfE) and Department of Agriculture, Environment and Rural Affairs (DAERA).

Education of the next generation of engineering biology practitioners becomes critical to sustain long-term development.

Long-Term (5-20 Years)

Long-term objectives centre on food security and supply chain resilience, developing Northern Ireland as a location where food systems innovation can thrive and be exported globally.

Role of Engineering Biology

Precision Agriculture: Using engineered microbiomes to enhance soil health, reduce chemical inputs, and improve crop resilience.

Animal Health and Productivity: Engineering animal genetics and developing biobased feed supplements to reduce methane emissions and improve efficiency.

Plant Improvement: Accelerating breeding programmes through gene editing technologies to develop crops with improved stress tolerance, nutritional content, and yields.

Biosecurity: Developing rapid diagnostic tools and bioengineered solutions for detecting and responding to plant and animal diseases.

Key Enablers

Northern Ireland possesses significant advantages, including concentrated expertise that facilitates collaboration, world-class research institutions, and the NI Diamond triple helix model that brings together government, industry, and academia. The region's scale makes comprehensive mapping and coordination feasible.

Critical Barriers and Risks

The lack of a specific engineering biology cluster means expertise is dispersed and not fully coordinated. Engineering biology activity has not been systematically mapped across Northern Ireland, making strategic planning difficult. GM regulations create uncertainty around deploying certain technologies. Most critically, there are significant capability gaps at TRL 3-4 levels, where innovations struggle to progress from laboratory to commercial scale.

Institutional silos present major challenges, with scope for DfE and DAERA to collaborate more efficiently. The divide between pre-farm gate (production) and post-farm gate (processing) innovation creates artificial barriers. Small and medium-sized enterprises (SMEs) lack the capacity to drive forward collaborative work without support, and there is no cluster manager to coordinate activities.

Required Actions

Immediate Actions

Funding is needed to create a cluster that unites and maps current activity in food security and engineering biology. Doctoral programmes specifically in engineering biology should be established, along with apprenticeship schemes to develop technical capabilities at multiple levels.

Systemic Changes

The DfE PhD awards system needs to explicitly include engineering biology as a priority area. More fundamentally, government departments must overcome the pre and post-farm gate divide, recognising that TRL 3-4 innovation crosses these boundaries. DAERA and DfE need mechanisms to join forces in supporting this critical middle stage of development.

Enabling the NI Diamond to mature requires sustained funding commitment. ‘Strength in Places’ level funding could unite and build engineering biology capabilities across the region. The focus should shift from artificial sectoral divisions to a holistic ‘food systems’ approach.

Desired Outcomes

Success means maintaining agricultural productivity in the face of climate change and other global challenges. Food systems would provide both human and planetary health benefits. Northern Ireland’s food sector would continue to thrive with evidenced credentials in food safety, traceability, and environmental sustainability, positioning the region as a global leader in climate-smart food production, underpinned by engineering biology innovation.

6.2 Case Study 2: Scale-up Capabilities

Summary

This initiative addresses a critical gap in Northern Ireland's engineering biology ecosystem: access to affordable capabilities for scaling innovations from laboratory towards commercial production. The focus is on developing regional scale-up infrastructure accessible to SMEs, with formal linkages into existing UK Catapult centres (including CPI, the Cell and Gene Therapy Catapult, and the HVM Catapult network) to provide pathways for later-stage scale-up. While appetite exists for greater Catapult presence in Northern Ireland, the prevailing stakeholder consensus favours regional scale-up facilities with structured access to existing UK Catapult centres as the most viable near-term model.

Strategic Context and Case for Development

A known market pull exists for scale-up capabilities in the pharmaceutical and biotechnology sectors. Both Industry and Academia representatives highlighted the need and case for intermediate-scale fermentation capacity. Specifically, a minimum of 1000 litre fermenter would enable Northern Ireland companies to win business currently lost to competitors with such infrastructure.

The UK has established six mission hubs in engineering biology, but none are located in Northern Ireland. Connection to the UK Catapult network - including Cell and Gene Therapy Catapult (CGT), Centre for Process Innovation (CPI), and Medicines Discovery Catapult (MDC) - is essential but currently inadequate.

Scope of Initiative

Within Scope

Enabling Affordable Access: The initiative focuses on making scale-up capabilities accessible to SMEs and university spin-outs at a reasonable cost.

Fermentation Capability: The priority is bridging fermentation capacity at 1000 litre scale locally, plus cell-free capability for emerging applications.

Local Presence: Establishing permanent Catapult staff in Northern Ireland to drive local capability, facilitate transitions to national facilities, and build relationships.

Outside Scope

The initiative explicitly avoids duplicating expensive existing national capabilities already present in Northern Ireland. The focus is on filling gaps, not creating redundancy.

Development Pathway and Timeline

Short-Term (1-3 Years)

Immediate focus is on utilising existing capabilities and adding capacity aligned with UK strategy. Current assets include the Food Manufacturing Innovation Centre (FMI), Almac facilities, the Advanced Manufacturing Innovation Centre (AMIC - though this is not its primary focus), and Fusion Antibodies.

Establishing connection to UK Catapults is urgent. Installing 1000 litre bridging fermentation capability locally and cell-free systems would address immediate industry needs. Permanent Catapult staff presence in Northern Ireland would catalyse relationship building and capability development.

Medium-Term (4-6 Years)

Development of a 'research hotel' model is envisioned, potentially building on all-Ireland collaboration. An all-island business case could leverage assets including Almac's UK and Ireland operations, University College Dublin expertise, skills development programs, and industry anchor tenants like Monaghan Mushrooms.

Long-Term (5-20 Years)

The long-term vision is a thriving ecosystem of engineering biology SMEs with easy access to scale-up capability and infrastructure, driving sustained economic growth in Northern Ireland.

Role of Engineering Biology

Biopharmaceutical Production: Fermentation systems for producing therapeutic proteins, antibodies, and other biologics.

Industrial Biotechnology: Scaling production of biobased chemicals, materials, and speciality products using engineered enzymes and organisms.

Cell-Free Systems: Emerging technologies for producing biologics without living cells, requiring specialised infrastructure.

Process Development: Bacterial and mammalian cell scale-up capabilities for optimising production before full commercialisation.

Key Enablers

Northern Ireland has established strengths to build upon. Queen's University Belfast offers an MSc in Engineering Biology. The BioAID initiative is an invaluable bioresource. Strong collaborative efforts are already ongoing between a number of the key regional actors. Entrepreneurship and commercialisation support programmes exist for PhD students and new companies. Establishing bacterial and mammalian scale-up capabilities will provide a good foundation. Existing infrastructure like FMI and AMIC can be grown and strengthened in linkage with the Catapult.

It was suggested during the report review stage that scale-up efforts may benefit from embedding process engineering aspects – including bioreactor design, downstream processing, mass and energy balance optimisation, and process control – from early TRL stages. Applying rigorous engineering design to biological systems reduces downstream scale-up risk and directly addresses the TRL 3-4 bottlenecks identified across multiple topic roadmaps. QUB's Faculty of Engineering and Physical Sciences has significant and growing capability in this space, with strategic investment in analytical chemistry, computational modelling, and scientific instrumentation directed towards renewables and bio-based chemicals.

Critical Barriers and Risks

A significant challenge is the declining focus on biomanufacturing more broadly, requiring a strategic pivot to extract relevant capabilities and redirect them toward engineering biology. The current lack of specialised skills and transferable skills in engineering biology creates workforce constraints. Few engineering biology companies currently operate in Northern Ireland, limiting demand signals.

Differentiation from the Republic of Ireland's offer is necessary, requiring clarity on Northern Ireland's unique selling proposition and how it fits into the UK capability landscape. Most critically, failing to capture and synergise with existing capacity across Northern Ireland, the rest of the UK and the Republic of Ireland would undermine the initiative.

Required Actions

Research and Planning

A comprehensive understanding of the current Northern Ireland, Republic of Ireland, and wider UK landscape is essential, identifying Northern Ireland's unique strengths and positioning. A detailed business case must be developed for Northern Ireland capability that meets industrial needs, supports university spin-outs and scale-ups, and attracts foreign direct investment opportunities.

Policy and Funding

The Department for the Economy should explore shared island and UK joint opportunities in engineering biology. DfE needs to derisk investment through appropriate mechanisms. Cost modelling for developing the ecosystem is required, potentially utilising pre-existing successful models like FMI.

Funding sources might include Local Investment Programme Funding (LIPF) and UK Research and Innovation (UKRI)/Innovate UK. Securing the buy-in of a large industry partner as an anchor tenant would provide credibility and guaranteed utilisation.

Strategic Framework

Development of a high-level actionable strategy for engineering biology in Northern Ireland is a prerequisite for coordinated progress.

Desired Outcomes

Success means enabling engineering biology companies to win business currently impossible due to infrastructure gaps. A thriving ecosystem of engineering biology firms and SMEs would have easy access to scale-up capability and infrastructure, driving economic growth. Northern Ireland would be integrated into UK and potentially all-Ireland engineering biology networks, with established pathways from laboratory innovation to commercial production.

6.3 Case Study 3: Circular Bioeconomy

Summary

This initiative focuses on developing renewable, traceable circular bioeconomy systems that utilise biomaterials and waste (including agricultural and fisheries waste) to create sustainable products and fuels. The approach keeps products in high-value loops, eliminates waste, creates new economic value chains, and enhances the natural environment.

Strategic Context and Case for Development

Lough Neagh provides both an environmental challenge and opportunity, serving as a focal point for demonstrating bioremediation approaches and thereby could act as a testbed to develop globally exportable solutions. Geopolitical events disrupting global supply chains underscore the need for locally sourced, renewable materials. European Union policy drives

sustainability targets and biobased solutions, particularly in packaging. Climate change impacts on agriculture, health, and water create urgency for circular approaches.

The initiative aims to position Northern Ireland as a green manufacturing region of excellence, achieving zero landfill through cascaded supply chains that are carbon neutral with zero waste or residual.

Scope of Initiative

Within Scope

Whole Lifecycle Consideration: Complete traceability of materials from source through use and eventual recycling or repurposing.

Bioremediation: Using biological systems to clean contaminated water and soil, with Lough Neagh as a primary focus area.

Agricultural Waste as Resource: Converting waste streams from agriculture into valuable products rather than disposal challenges.

Biopolymers: Developing bio-based alternatives to synthetic polymers for packaging and other applications.

Circular Loops: Creating closed-loop systems where outputs from one process become inputs for another.

Outside Scope

Incineration is explicitly excluded as being contrary to circular economy principles.

Development Pathway and Timeline

Short-Term (1-3 Years)

Immediate drivers include EU sustainability targets, biobased solutions requirements, and packaging regulations. The Advanced Manufacturing Innovation Centre (AMIC) serves as a key capability hub, with partnerships extending to UK and Irish centres.

A flagship project would establish bioremediation in Lough Neagh, potentially harvesting algae which might be used to create polyhydroxyalkanoate (PHA) polymers. This addresses both environmental restoration and creates a valuable product stream. Comprehensive mapping of key stakeholders and current state of play is essential, along with identifying applications and opportunities across sectors.

Medium-Term (4-6 Years)

Climate change impacts on agriculture, health, and water intensify, driving adoption of circular solutions. Product development advances to modified proteins for barrier applications in packaging. Coordinated circular bioeconomy clusters emerge, with North-South (all-Ireland) coordination becoming operational.

Long-Term (5-20 Years)

Infrastructure is in place to utilise biological and agricultural waste for large-scale production and use of bio-derived fuels. The Lough Neagh bioremediation model is exported as a toolkit to other regions facing similar challenges. Northern Ireland serves as a blueprint for circular bioeconomy implementation globally.

Role of Engineering Biology

Bioremediation Systems: Engineered algae and microorganisms that efficiently remove pollutants from water while producing valuable biomass.

Biopolymer Production: Organisms engineered to convert agricultural waste or algae into PHA polymers, polyhydroxybutyrate (PHB), and other bioplastics that are biodegradable and perform comparably to synthetic alternatives. These might require growth in isolation from wild strains.

Protein Engineering: Modified proteins designed for specific barrier properties in food packaging, replacing synthetic materials with biodegradable alternatives.

Bioprocessing Optimization: Engineered enzymes and metabolic pathways that improve efficiency of converting waste streams into valuable products.

Microbial Consortia: Designed communities of microorganisms that work together to break down complex waste materials and synthesize target products.

Key Enablers

AMIC provides strong expertise in polymers and composites, with established polymer design and manufacturing capabilities. Workshop participants also identified AMIC as a potential bridge to CPI with a distinct UK offer in materials processing, noting that adding biological capability to AMIC's existing strengths could address a critical gap. The Northern Ireland Polymers Association (NIPA) offers industry coordination. Knowledge Transfer Partnerships (KTP) facilitate academic-industry collaboration. All-Ireland collaboration models exist to build upon, particularly for circular bioeconomy clusters.

Critical Barriers and Risks

Cost competitiveness remains a major challenge, as biobased materials currently cannot compete economically with synthetic alternatives at scale. Waste legislation paradoxically sometimes prohibits circular economy approaches through restrictive definitions of what constitutes 'waste' versus 'resource.'

Technology readiness gaps at TRL 4-6 levels hinder scaling from prototype to production. Lack of coordination and visibility across value chain players creates inefficiencies. Sectoral silos prevent the cross-industry collaboration essential for circular systems. Contamination issues in waste streams complicate processing. High energy costs in Northern Ireland affect economic viability of energy-intensive bioprocessing.

Required Actions

Policy and Strategy

Better coordination of local strategy and policy is essential, with improved lobbying of UK government on circular economy priorities. Interdisciplinary skills development programmes are needed. Most critically, a comprehensive circular economy strategy must bring together DfE and DAERA in collaboration, breaking down traditional pre/post farm gate divisions.

Immediate Practical Steps

The Lough Neagh initiative should proceed with exploring the farming of algae to create PHA polymer, serving as both environmental remediation and economic development, although there are challenges with using this method. Comprehensive mapping of key stakeholders,

current capabilities, and applications must be completed. Waterways bioremediation using seaweed and algae for polymer production should be explored beyond Lough Neagh.

Developing an off-take model where products from circular processes have guaranteed buyers would reduce investment risk. Tracking and mapping biological materials through sectors and systems would identify opportunities for circularity.

Infrastructure and Research

Feasibility studies for modular biorefinery concepts for algae processing are needed. A roadmap for circular bioeconomy development should be created, with AMIC potentially leading this mapping exercise. Universities (Ulster and Queen's) and AMIC would deliver applied research and accelerate prototype to production deployment with lean integration. Industry must share waste data, participate in test beds, and commit to deployment when technologies prove viable.

Funding Requirements

Common Agricultural Policy (CAP) funding could establish a circular bioeconomy cluster. Feasibility and proof of concept funding is needed within 12-15 months. Longer-term, millions of pounds will be required for large-scale deployment.

Desired Outcomes

Success delivers a connected cluster with a clear roadmap and business cases ready for investment. Lough Neagh becomes clean through bioremediation that also generates economic value. Emissions are reduced and heat decarbonised through bioderived fuels and materials. Northern Ireland serves as a champion cluster for dissemination across the world, exporting both the remediation toolkit and the circular economy model. The region achieves recognition as a leader in green manufacturing, with zero landfill achieved through cascaded, circular supply chains.

6.4 Case Study 4: Agri-Tech Innovation and Policy Alignment

Summary

This initiative addresses the disconnect between Northern Ireland's small but technologically advanced Agri-tech sector and the broader innovation ecosystem. The focus is on better policy alignment to create a commercially and environmentally sustainable Agri-tech sector that develops technology locally, tests it in Northern Ireland's unique agricultural context, and sells solutions globally.

Strategic Context and Case for Development

Northern Ireland has untapped potential for engineering biology development in Agri-tech. The region features a small Agri-tech sector serving a large number of small, often part-time farms. This creates a paradox: substantial agricultural activity with limited technology adoption, but potentially data-rich environment if systems can be integrated.

The export-oriented nature of Northern Ireland agriculture (approximately 80% of production is exported) means locally developed solutions must meet international standards, potentially giving them global applicability. The small regional scale makes Northern Ireland an ideal living laboratory where innovations can be tested comprehensively before broader deployment.

Scope of Initiative

Within Scope

Regulatory Compliance: Ensuring engineering biology technologies meet all relevant regulations while enabling innovation.

Engineering Biology Supporting Sustainable Primary Production: Technologies that directly improve on-farm sustainability and productivity.

Data Infrastructure: Creating systems where data informs engineering and biology manipulation, including genomics applications. The principle of 'if you can't measure it, you can't manage it' drives focus on technologies that measure biological systems.

Outside Scope

Agri-food processing and broader primary production issues are explicitly excluded, with focus maintained specifically on the technology layer enabling sustainable agriculture.

Development Pathway and Timeline

Short-Term (1-3 Years)

The immediate focus is on connecting, understanding, and tracking existing capabilities and data sources. Establishing relationships and trust with the farming community is paramount, as data security concerns create significant barriers to participation.

Medium-Term (4-6 Years)

Artificial intelligence, increased value of data, and advancing gene sequencing technologies become key drivers. Accessible data platforms emerge to allow engineering biology product development in Agri-tech. This is the critical period where technology readiness gaps must be bridged.

Long-Term (5-20 Years)

A mature, aligned system emerges connecting government, industry, academia, and citizens - a quadruple helix model. Technologies developed and tested locally in Northern Ireland are successfully sold to global markets, with Northern Ireland established as a centre for Agri-tech innovation built on engineering biology foundations.

Role of Engineering Biology

Precision Livestock Management: Biosensors and engineered diagnostic tools for real-time animal health monitoring, enabling early disease detection and optimized nutrition.

Soil Microbiome Engineering: Understanding and manipulating soil microbial communities to improve nutrient management, reduce chemical inputs, and enhance soil health.

Genomic Selection Tools: Using gene sequencing data to inform breeding decisions for both plants and animals, accelerating improvement in key traits like disease resistance and environmental stress tolerance.

Biological Control Systems: Engineered organisms or biological products for sustainable pest and disease management in crops and livestock.

Environmental Sensing: Biological sensors for monitoring environmental parameters critical to sustainable farming, including water quality, soil health indicators, and pathogen presence.

Key Enablers

Northern Ireland possesses significant advantages for Agri-tech development. The abundance of farms provides extensive opportunities for on-farm testing and validation. World-class centres of excellence in agricultural research, particularly at Queen's University Belfast and the Agri-Food and Biosciences Institute (AFBI), provide scientific foundation. Strong livestock policy frameworks and soil nutrient management regulations create a structured environment for deploying new technologies.

Critical Barriers and Risks

Legacy data systems are inaccessible, with valuable historical information trapped in formats that cannot be easily integrated with modern analytical tools. The structure of Northern Ireland agriculture - dominated by small, part-time farms - creates challenges for technology adoption and data collection at scale.

Government departments have fragmented approaches with varying definitions of what constitutes 'Agri-tech' and 'engineering biology,' potentially creating confusion and inefficiency. Most critically, data security concerns among farmers regarding government access to farm-level data could create significant trust barriers.

Required Actions

Immediate Critical Action

Making relevant data available in secure, accessible format is the go/no-go decision point for this initiative. Without solving data access while protecting farmer privacy and addressing legitimate security concerns, the initiative cannot progress. This requires early engagement with DAERA and AFBI to establish trust and appropriate governance frameworks.

Research and Development Requirements

Organisation and accessibility of data must be addressed systematically. This likely requires significant investment to modernize systems, establish interoperability standards, and create secure access protocols that protect individual farmers while enabling population-level analysis.

Ecosystem Development

DAERA is the clear lead agency, but support is needed from complementary organisations. The Artificial Intelligence Collaboration Centre could provide data science and AI expertise. Digital Catapult offers technology scaling support. The UK Agri-Tech Centre network provides best practice examples and potential partnerships.

Investment Requirements

While the quantum of funding required remains to be fully determined, it is likely to be significant. Data infrastructure modernisation, secure platform development, and establishing the necessary governance frameworks all require substantial investment.

Desired Outcomes

Success creates a commercially and environmentally sustainable Agri-Tech sector in Northern Ireland where government, industry, academia, and citizens are aligned through a quadruple helix model. Technology developed locally is tested in Northern Ireland's agricultural context and sold globally. The region becomes recognised for its unique combination of digital resources, agriscience capability, life science expertise, and emerging living laboratory status. Agriculture operates as a data-informed sector where engineering biology innovations can be rapidly deployed, tested, and refined before global scaling.

6.5 Case Study 5: Diagnostics and Biosensors

Summary

This initiative aims to develop the complete pipeline for diagnostic design, prototyping, and manufacturing, positioning Northern Ireland as a diagnostics powerhouse. The focus spans molecular and protein design, RNA-based diagnostics, lateral flow multiplex systems, incubation technologies, and the laboratory infrastructure necessary to support innovation and commercialisation.

Strategic Context and Case for Development

Northern Ireland possesses an established diagnostics industry with significant global presence. Extensive diagnostic research occurs across universities and research institutes. The initiative aligns with One Health principles, addressing diagnostics needs spanning human health, animal health, and environmental monitoring. The growth in health sector spending and increasing Agri-tech sophistication create expanding markets for diagnostic innovations.

The initiative addresses grand challenges in health and agriculture, national sustainability goals, and emerging opportunities from lower barriers to entry as diagnostic technologies become more accessible. The sector aligns with DfE and Invest Northern Ireland strategic priorities, NHS Reset Plan objectives, and Northern Ireland City Growth Deals.

Scope of Initiative

Within Scope

Designed Biomolecules: Engineering proteins, nucleic acids, and other biomolecules specifically for diagnostic applications.

Complete Pipeline Development: Addressing the 'valley of death' between research and commercialisation by developing capabilities at all stages from concept to market.

Advanced Platforms: Lateral flow multiplex systems allowing simultaneous detection of multiple targets, incubation technologies, and platform development for point-of-care applications. Also associated integrated photic/electronic solutions for accurate reading.

Laboratory Infrastructure: Hostable, rentable laboratory space that SMEs and startups can access without prohibitive capital investment.

Optimisation and Characterisation of immobilisation methodologies for target-detection protein chemistries on nanoparticle surfaces for sensing and therapeutic integrated applications across a wide range of disease types.

Outside Scope

Established, mature diagnostic products and markets are excluded, with focus maintained on innovation and emerging applications where engineering biology provides an advantage.

Development Pathway and Timeline

Short-Term (1-3 Years)

Immediate focus is on establishing a diagnostics forum, potentially through the Health Innovation Research Institute Northern Ireland (HIRANI) network. Local academic training schools on biosensor design and diagnostic development should be launched. These provide both skills development and networking opportunities.

Biomarker development and design work can begin relatively quickly and cost-effectively, providing proof-of-concept demonstrations. Shared resources across projects would improve efficiency and reduce duplication. A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the sector should be completed to inform strategic planning.

Medium-Term (4-6 Years)

Strong commercial cases emerge for specific diagnostic applications. Laboratory infrastructure becomes available – ideally, hostable and rentable to reduce barriers for startups. A bespoke accelerator programme specifically for diagnostics and biosensors companies is established, moving beyond generic business support to provide sector-specific guidance and connections.

Commercial partner identification and relationship building become critical. An experienced entrepreneur pool provides guidance, helping prevent common pitfalls and accelerating commercialisation. Skills development and training programmes mature, preventing brain drain of talent to other regions.

Long-Term (5-20 Years)

National sustainability goals drive continued demand for innovative diagnostics. Lower barriers to entry enabled by improved infrastructure and skills base allow new companies to form. The diagnostics forum evolves into a mature cluster with sustained commercial success and sector sustainability. Northern Ireland is recognised internationally as a diagnostics powerhouse.

Role of Engineering Biology

Biomolecular Design: Engineering proteins, antibodies, aptamers, and nucleic acid probes with enhanced specificity, sensitivity, and stability for target detection.

Biosensor Development: Creating biological recognition elements (enzymes, antibodies, DNA/RNA sequences) that detect specific biomarkers and transduce binding into measurable signals.

Synthetic Biology Circuits: Designing genetic circuits that provide signal amplification, logic gates for multi-input diagnostics, and programmable responses.

Cell-Free Systems: Using engineered cellular machinery outside living cells for rapid, stable diagnostic reactions.

Multiplexing Capabilities: Engineering systems that can simultaneously detect multiple targets accurately and specifically, critical for comprehensive disease screening and environmental monitoring.

Point-of-Care Adaptation: Modifying biological components for stability and function in resource-limited settings, enabling diagnostics beyond traditional laboratory environments.

Key Enablers

Northern Ireland has a highly skilled workforce in diagnostics and biosensors across multiple disciplines. A thriving diagnostics sector provides industry foundation and commercial pathway examples. Internationally recognised academic research excellence at Queen's University Belfast, Ulster University, AFBI, and Health and Social Care Trusts provides scientific depth.

The £30 million investment in Nanotechnology and Photonics capabilities at AMIC provides advanced instrumentation and expertise. The Northern Ireland Biomedical Engineering Centre (NIBEC) at Ulster University, which will be developed into the city Deal Centre for Digital Healthcare Technology (CDHT), offers complementary capabilities. Advanced analytical and characterisation capabilities – including chromatography, mass spectrometry, and spectroscopy – are equally important as translational infrastructure, supporting reaction monitoring, impurity profiling, and regulatory-grade validation as diagnostic technologies move toward commercial deployment. Local training infrastructure and Knowledge Transfer Partnerships enable skills development and technology transfer.

Existing networks like HIRANI provide coordination frameworks to build upon. Alignment with NHS Reset Plan – particularly 'health at home/community' emphasis – creates demand for point-of-care diagnostics.

Critical Barriers and Risks

The sector lacks a complete pipeline from concept to commercialisation. Connectivity could be enhanced – expertise exists but is not optimally networked. Gaps in grant and venture capital funding create financing challenges, particularly for the expensive late-stage development required for regulatory approval. Specific skills gaps exist in biomolecular discovery, synthetic biology, and some nanoengineering areas.

Lack of collaboration and knowledge sharing creates inefficiency and duplication. 'Too much talk and too little action' risks breeding cynicism and lethargy, undermining momentum. Ethical approval regulations could be too slow for the pace of innovation. Most critically, lack of investment and no appetite for risk among potential funders would limit commercialisation even when science succeeds.

Connections with large biotechnology corporations are weak, limiting access to partnerships, distribution channels, and acquisition opportunities. Data privacy requirements and GDPR compliance add complexity to diagnostic development, particularly for human health applications.

Required Actions

Immediate Actions

Establish a diagnostics forum through HIRANI or as a more focused subgroup, creating regular interaction among researchers, clinicians, and industry. Identify all stakeholders through discussion forums to understand full ecosystem. Launch local training schools specifically on diagnostics and biosensor design, going beyond generic programmes to provide specialised technical knowledge.

Research and Development Priorities

Investigate how biosensors can translate across sectors - from human health to animal health to environmental monitoring - maximising technology leverage. Create platform funding rather than disease-specific or application-specific funding, allowing foundational technology development that serves multiple markets.

Develop a business case for investment, outlining clear vision and return potential. Use MATRIX (Northern Ireland Science Industry Panel) to conduct capability mapping, understanding what exists and where gaps lie. Build comprehensive biomarker and biosensor databases capturing knowledge currently scattered across literature and institutions.

Infrastructure and Skills Development

Develop a bespoke accelerator program tailored to diagnostics companies, providing sector-specific mentorship, connections, and resources. Invest in biomarker development and design capabilities, which are relatively quick and inexpensive ways to demonstrate potential. Ensure shared resources across projects, avoiding duplication of expensive equipment and expertise.

Maximise research capability through enhanced data mining and creating platforms where valuable datasets can be accessed by multiple researchers ethically and efficiently. Skills development and training programmes should target identified gaps, particularly in synthetic biology, biomolecular discovery, and advanced nanoengineering.

Ecosystem Development

HIRANI should lead the diagnostics forum, leveraging its existing health innovation networks. Queen's University Belfast, Ulster University, and AFBI should lead training schools with outreach extending beyond their immediate networks. DfE should form strategic connections with large biotechnology corporations and consider direct investment or de-risking mechanisms to encourage private sector participation.

Funding Strategy

Monetary investment is needed for both R&D and infrastructure. Non-monetary support through steering group establishment provides strategic guidance and coordination. Focus funding on platforms rather than specific applications, building foundational capabilities with multiple potential applications.

Desired Outcomes

Success means capacity to address grand challenges in health, agriculture, and biotechnology, while capturing emerging market opportunities. The established diagnostics sector continues thriving while new companies form and grow. Internationally recognised research excellence translates into commercial success and job creation.

The complete pipeline from concept through design, prototype, and manufacture operates efficiently, eliminating the valley of death. Enhanced sector connectivity allows collaboration and knowledge sharing while maintaining competitive dynamics. Research capabilities are fully leveraged through comprehensive data mining and shared resources.

Skills gaps are filled through targeted training, preventing brain drain and attracting international talent. Northern Ireland is recognised as a diagnostics powerhouse globally, with sustained sector sustainability and growth. The region serves as a model for how engineering biology can transform diagnostic capabilities across multiple domains.

6.6 Case Study 6: One Health

Summary

This initiative explores how bioengineering can be employed across One Health domains in Northern Ireland to impact global health. One Health recognises the interconnection of human health, animal health, and environmental health, requiring coordinated approaches that address all three simultaneously. The initiative investigates whether bioengineering provides the tools necessary to address One Health challenges effectively.

Strategic Context and Case for Development

Multiple converging factors create urgency for One Health approaches. Climate change drives zoonotic disease emergence, increases pandemic risk, and accelerates antimicrobial resistance (AMR) development. Fragile ecosystems face mounting pressures. Changing health needs across human and animal populations require adaptive solutions. EU policy increasingly mandates One Health frameworks.

The initiative builds on existing platforms, including industry-led animal health initiatives and the Special EU Programmes Body (SEUPB) One Health initiative. One Health allies across sectors provide foundation for expanded collaboration. Northern Ireland's scale and integrated agricultural, health, and environmental systems make it an ideal testbed for One Health innovations.

Scope of Initiative

Within Scope

Bioengineering as a Tool: Focus on how engineering biology can address One Health challenges across human, animal, and environmental health domains.

Policy Development: Creating a One Health policy framework specific to Northern Ireland's context and needs.

Cross-Sectoral Integration: Breaking down silos between human health services, agricultural/veterinary sectors, and environmental management to enable coordinated responses.

Outside Scope

While Northern Ireland is certified free of certain plant pathogens, broader plant pathogen research and management are excluded from this particular initiative's focus.

Development Pathway and Timeline

Short-Term (1-3 Years)

Immediate drivers include global warming's effects on zoonotic diseases, pandemic preparedness, and antimicrobial resistance. The established Agri-food sector provides both challenge and opportunity. Existing initiatives can be built upon rather than starting from zero.

Critical early actions include conducting gaps analysis to understand where bioengineering tools exist versus where they are needed. Data management and storage infrastructure must be developed. Skills development is essential, covering both general One Health competencies and specialised bioengineering capabilities.

Establishing multi-stakeholder collaborations brings together agricultural actors, health services, environmental agencies, and research institutions. An Agri-food forum can provide coordination platform. Bioinformatics and data science capabilities are foundational for integrating information across domains.

Medium-Term (4-6 Years)

Sustainable ruminant genetics programmes in Northern Ireland mature, potentially incorporating bioengineering approaches. Biodiversity conservation becomes increasingly urgent as climate impacts intensify. Targeted funding for One Health applications emerges as the framework proves valuable.

Development of plug-and-play platforms allows rapid deployment of bioengineering solutions. Cross-cutting developments include vaccines for wild animals that prevent or reduce disease transmission to humans - a critical interface where One Health principles are essential. Industry compliance with One Health regulations drives adoption. Cross-sector steering groups become operational. A dynamic genetic evolution database tracks pathogen changes across human, animal, and environmental reservoirs.

Long-Term (5-20 Years)

Resistant livestock and plants are developed through selection and potentially GMO approaches, with cultivars and animal breeds better adapted to Northern Ireland's changing conditions. Comprehensive biodiversity conservation strategies are implemented, using bioengineering where appropriate to support ecosystem resilience.

Role of Engineering Biology

Disease Surveillance and Diagnostics: Rapid, cost-effective diagnostic tools for detecting pathogens across human, animal, and environmental samples using bioengineered recognition elements and amplification systems.

Understanding Infectious Disease Dynamics: Genomic surveillance and bioinformatics revealing how pathogens move between species, environments, and populations, enabling predictive modelling and early intervention.

Pathogen Surveillance Systems: Engineered biosensors deployed in agricultural settings, water systems, and healthcare facilities providing real-time monitoring across plant, animal, and human populations.

Vaccine Development: Cross-species vaccine platforms using recombinant proteins or viral vectors that can be rapidly adapted as pathogens evolve or emerge. Wildlife vaccination strategies to create buffer zones preventing spillover to livestock and humans.

Antimicrobial Resistance Solutions: Engineered alternatives to conventional antibiotics, including bacteriophage therapy, antimicrobial peptides, and CRISPR-based approaches targeting resistance genes.

Ecosystem Restoration: Bioengineered microorganisms for soil health restoration supporting both agricultural productivity and broader ecosystem functions. Conservation biology approaches using genetic tools to maintain biodiversity.

Climate Adaptation: Developing crop cultivars and animal breeds with enhanced resilience to climate stressors, reducing pressure on ecosystems while maintaining food security.

Key Enablers

Northern Ireland has multiple advantages for pioneering One Health approaches. Soil health restoration and conservation efforts are underway, providing practical contexts for bioengineering applications. Multi-stakeholder collaboration traditions exist, particularly in the agri-food sector. Various actor forums bring together industry, research, and government.

Strong bioinformatics and data science capabilities, particularly at Queen's University Belfast, enable the data integration essential for One Health. Industry demonstrates willingness to comply with One Health regulations when properly structured. Cross-sector steering groups can build on existing coordination mechanisms. Biodiversity surveys in Northern Ireland provide baseline data for conservation bioengineering. Capacity exists to develop dynamic genetic evolution databases tracking pathogens.

Critical Barriers and Risks

Skills retention presents a major challenge – developing One Health expertise requires sustained career pathways or talent will migrate elsewhere. Isolated sectors operate independently while One Health requires integration. Lack of communication between sectors wastes opportunities for synergy. Access to coordinated funding in Northern Ireland is limited, with few ring-fenced resources for One Health approaches.

Data management and sharing face technical and governance barriers. Different sectors collect data in incompatible formats, with varying access restrictions. Most critically, public perception of bioengineering – particularly genetic modification of animals and plants – creates acceptance challenges even when technologies offer clear benefits. Regulatory uncertainty around novel bioengineering applications in agriculture and environment slows progress.

Required Actions

Immediate Actions

Map and build upon existing One Health initiatives, including SEUPB programmes and industry-led activities. Conduct comprehensive gaps analysis identifying where bioengineering tools exist, where they are needed, and what barriers prevent deployment. Establish a One Health forum bringing together all relevant sectors for regular coordination and knowledge sharing.

Policy and Governance

Multi-agency policy development is essential, creating Northern Ireland and all-Ireland tailored perspectives for One Health rather than adopting frameworks designed for different contexts. Policy and regulations must clarify One Health's place within the bioeconomy framework. Consistent and complementary policy alignment is required across Department for the Economy, Department of Agriculture, Environment and Rural Affairs, and Department of Health.

Government departments must provide support, facilitation, and funding. Training designated staff across sectors in One Health principles and bioengineering applications creates internal champions. Lobbying at UK and EU levels ensures Northern Ireland priorities are represented in broader policy development.

Research and Development

Platform development for diagnostics, therapeutics, monitoring systems, and vaccines across sectors should be prioritised. These foundational technologies serve multiple One Health applications. Ring-fenced specific funding targeted at bioengineering to address One Health challenges in Northern Ireland is needed, distinct from general health or agricultural research budgets.

Infrastructure and Capabilities

Establish dedicated resources including both funding and physical space for One Health initiatives. Data sharing platforms with appropriate governance enable integration across sectors while protecting privacy and commercial interests. Skills development programmes should train both specialists with deep bioengineering expertise and generalists who can work across One Health domains.

Stakeholder Engagement

Cross-sector steering groups should be operational by 2026, including representatives from government, universities and research institutes, industry (through representative bodies like Dairy Council), Health and Social Care, and charitable sector funders. Higher education and R&D institutes must demonstrate strategic buy-in beyond rhetoric. Technology development must align explicitly to One Health needs rather than pursuing bioengineering for its own sake.

Timeline and Milestones

A cross-sector steering group should be established in 2026. Dedicated resources (funding and physical space) may be secured in 2027. New bioengineering tools applied across sectors should result in marketed products from 2030 onwards, demonstrating tangible impact of the One Health approach.

Desired Outcomes

Success means better understanding of how human, animal, and environmental health components interact and impact global health. Bioengineering provides practical, deployable tools for addressing One Health challenges across all domains. Northern Ireland serves as a model for integrated One Health implementation, demonstrating how bioengineering accelerates solutions.

Infectious disease dynamics are understood and managed proactively rather than reactively. Pathogen surveillance operates continuously across plant, animal, and human populations, enabling early detection and response. Vaccines for wild animals create protective barriers, reducing spillover risk. Antimicrobial resistance is addressed through alternative therapies and better stewardship informed by comprehensive surveillance.

Ecosystems are restored and protected, supporting biodiversity while enabling sustainable agriculture. Crop cultivars and animal breeds adapted to Northern Ireland's changing climate maintain productivity without environmental degradation. The region demonstrates that economic development, public health, and environmental protection can advance together when One Health principles guide bioengineering innovation.



SWOT Analysis

Chapter 7: SWOT Analysis

This chapter presents a consolidated Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis for engineering biology in Northern Ireland. The analysis synthesises evidence gathered from the literature review, stakeholder engagement and workshop. The SWOT is structured to reflect Northern Ireland's current position and future strategic options across healthcare and medicine, agri-food and environment, industrial biotechnology, and environmental solutions. The findings are presented as bulleted assessments under each SWOT category. Where appropriate, cross-references to specific topic roadmaps, stakeholder interviews, and global insights are noted to support the assessment. The analysis also incorporates the opportunity-feasibility scores assigned by workshop participants to each of the six priority initiatives.

7.1 Strengths

Research and Academic Excellence

- Internationally recognised research base across two research-intensive universities. Queen's University Belfast has particular strengths in precision medicine, food security and diagnostics, stratified medicine, antibody engineering, and nanomaterials for therapeutics. Ulster University contributes leading capability in personalised medicine, biosurfactant fermentation, diagnostics development and digital healthcare, and the Northern Ireland Centre for Stratified Medicine in Derry/Londonderry.
- The Agri-Food and Biosciences Institute (AFBI) provides government-backed research excellence in animal health, environmental monitoring, bioinformatics, and disease surveillance, including significant work on bovine tuberculosis genomics and blue-tongue virus diagnostics.
- Strong track record of translational research outputs, including Aviceda's nanomaterial-based therapeutics (now in late-stage clinical trials internationally), Fusion Antibodies' antibody engineering platform, and COVID-19 rapid diagnostic tests designed and manufactured in the region.
- Established postgraduate training infrastructure, including Queen's Biopharma Engineering Masters programme developed in partnership with Eli Lilly, and the NI Lab doctoral programme as a successful QUB-Ulster University partnership model.

Industry and Sectoral Capabilities

- Companies with global reach provide a strong industrial foundation. A large company operates across the full drug development pipeline with particular strength in bioprocessing, peptide chemistry, companion diagnostics, and biocatalysis. Radox Laboratories is a world leader in diagnostics, biosensors, and bioinformatics. Norbrook Laboratories leads in veterinary pharmaceuticals, with direct relevance to the agri-food sector. Beyond life sciences, Northern Ireland has a strong engineering polymers supply chain and R&D base, supported by AMIC and industry bodies such as NIPA, with companies pioneering work in areas including circularity and bio-based materials.⁴⁴
- A thriving diagnostics and biosensors ecosystem, recognised as one of Northern Ireland's most established engineering biology strengths. Workshop participants scored the Diagnostics and Biosensors initiative at 4 for both opportunity and feasibility, reflecting mature capabilities and clear market alignment with DfE/INI strategic priorities, the NHS Reset Plan, and NI City Growth Deals.

⁴⁴ NI's polymer sector employs 1 in 6 of the region's manufacturing workforce and generates £1 in every £8 of manufacturing output (NIPA, 2025). NI-based Plaswire is pioneering circular recycling of wind turbine blades into reusable RX polymer (Plaswire/ubloquity, 2025), while Denroy leads a £3.8m ATI-funded project on thermoplastic composites for aerospace (Belfast Newsletter, 2022).

- Established precision medicine cluster anchored by the Precision Medicine Centre of Excellence at Queen's, Diagnostic Services of a large company, Diaceutics, and Randox, with demonstrated strength in companion diagnostics and stratified medicine approaches.
- The largest agri-food sector in the United Kingdom as a proportion of regional GDP, producing sufficient protein for approximately seven million people. This provides a substantial demand base and testing ground for engineering biology applications in food security, biosensors, precision breeding, and sustainable agriculture.

Strategic Positioning and Infrastructure

- Unique dual market access through the Windsor Framework, enabling products developed and regulated in Northern Ireland to satisfy both MHRA (UK) and EU regulatory requirements simultaneously. Multiple interviewees, from industry and academia, identified this as a potentially significant competitive advantage for attracting foreign direct investment and clinical trials, provided it is proactively leveraged.
- Significant new infrastructure investments through the Belfast Region City Deal, including the Future Medicines Institute (FMI) at Queen's, the Advanced Manufacturing Innovation Centre (AMIC) with £30 million in Nano Technology and Photonics capability, and the iReach clinical trials facility, all of which create industry-facing platforms for engineering biology scale-up.
- Small regional scale offers inherent advantages of agility, interconnectedness, and the ability to convene key stakeholders rapidly. Several interviewees noted that "everybody knows everybody" in Northern Ireland's innovation ecosystem, enabling faster consensus-building and collaborative action than in larger regions.
- Strong all-island collaboration potential, exemplified by the IMPACT initiative (€100 million Research Ireland funding for personalised advanced cell therapies) and existing cross-border research partnerships. When the all-island population of approximately 6-7 million is considered together, the region approaches the scale of established biotech hubs such as Boston or Philadelphia.

7.2 Weaknesses

Infrastructure and Scale-Up Deficits

- Critical absence of a life sciences Catapult or equivalent scale-up facility. Northern Ireland has no CPI-type bioengineering centre, and companies cannot access the specialist equipment or shared manufacturing infrastructure needed to progress from laboratory research to commercial production. Workshop participants scored the Large-Scale Capabilities initiative at 5 for opportunity but only 3 for feasibility, reflecting the magnitude of this gap.
- Loss of domestic manufacturing know-how, particularly in synthetic chemistry and reagent production. Northern Ireland no longer has local capacity for manufacturing primers, antibodies, recombinant proteins, or DNA/RNA synthesis—all of which must be imported. This dependency creates supply chain vulnerabilities exposed during the COVID-19 pandemic and leaves the region unable to capture the full value chain from its own research.
- A persistent 'valley of death' between academic research and commercial application. Individual companies, universities, and academics develop promising technologies, but there is no shared innovation space or structured pathway for low-level manufacture, prototyping, and early-stage commercialisation.
- Analytical and characterisation infrastructure, process engineering expertise, and computational chemistry capabilities are not yet systematically integrated into engineering biology programmes, limiting translational reliability and increasing downstream scale-up risk.

Skills and Workforce Challenges

- Skills gaps were identified as the single most consistently cited barrier across all stakeholder engagements. DfE representatives confirmed that skills are “consistently the top barrier” across all sectors. Specific deficits exist in biomolecular discovery, synthetic biology, biomanufacturing process engineering, regulatory expertise, data science applied to biology, and entrepreneurial training.
- Industry-readiness deficit among graduates: employers report that graduates frequently lack practical laboratory skills, soft skills such as teamwork and communication, and commercial awareness. The disconnect between academic training and industry requirements was highlighted by multiple interviewees.
- Brain drain to the Republic of Ireland and Great Britain, driven by higher salaries, greater career opportunities, and a perception that Northern Ireland offers insufficient progression pathways in life sciences. The Treasury assumption of maximum UK employment does not account for Northern Ireland’s specific talent retention challenges.
- A shortage of clinical academics – professionals with both clinical practice and research expertise – limiting Northern Ireland’s ability to conduct advanced cell therapy trials and other translational research requiring medical and scientific dual competence.

Strategic Coordination and Funding

Fragmented strategic landscape with no unified coordination mechanism for engineering biology. Multiple interviewees called for a single individual with “convening authority” rather than another committee to bring together existing assets, research strengths, and industry capabilities into a coherent strategy.

No Office for Life and Health Sciences is bridging the health and economy departments. Interviewees highlighted that the health department does not always recognise the economic value of life sciences innovation, and the economy department lacks health system expertise, creating a structural gap in policy coordination.

Historically poor engagement with competitive UK-wide funding mechanisms. Northern Ireland has underperformed in securing Innovate UK, UKRI, and Horizon Europe funding, partly due to a cultural perception that such bids are too competitive and partly because the region’s case is not well understood by UK-wide funders. UKRI data shows Northern Ireland receives approximately 1% of total UKRI funding despite comprising 2.8% of the UK population⁴⁵. None of the six national UKRI engineering biology hubs are led from Northern Ireland.

Limited venture capital presence and risk capital availability. Start-ups report being advised to relocate to Great Britain or elsewhere to access funding, and the region lacks the depth of specialist biotech investors found in competing locations such as the Golden Triangle, Edinburgh, or Dublin.

Sectoral silos and poor cross-disciplinary communication. The ‘One Health’ topic roadmap group identified isolated sectors with poor communication between health, agriculture, environment, and industry as a fundamental weakness, compounded by a lack of ringfenced cross-sectoral funding.

⁴⁵ UKRI, Geographical Distribution of UKRI Funding, Financial Years 2022 to 2023 and 2023 to 2024 (2024). NI’s share has been growing – a 43% proportional increase between 2021–22 and 2023–24, the largest of any UK area – but from a low base.

7.3 Opportunities

High-Priority Sector Opportunities

- Food security and resilience through engineering biology was scored 5 for opportunity (the highest of any initiative) and 3 for feasibility. Northern Ireland's position as the UK's largest agri-food producer relative to GDP, combined with academic strengths at the Institute for Global Food Security and AFBI, creates a compelling platform for precision breeding, engineered soil microbes, fermentation-based food ingredients, and enhanced food safety and traceability systems.
- The Lough Neagh environmental crisis presents a distinctive and politically salient opportunity. Technologies addressing algal bloom remediation, water quality biosensors, and bioremediation would have immediate local application and significant export potential if proven effective. The Circular Bioeconomy initiative scored 4 for opportunity, with pathways to modular biorefineries utilising agricultural and aquatic waste.
- Advanced cell therapies and personalised medicine, building on the IMPACT all-island initiative and Northern Ireland's established precision medicine cluster. The reactivation of the cell pharmacy at the Royal Victoria Hospital and participation in all-island clinical trial networks could enable patients to receive cutting-edge treatments locally rather than travelling to Manchester or London.
- Diagnostics value chain completion: Northern Ireland possesses strong diagnostic development capability but has lost manufacturing capacity. Rebuilding this capacity would allow the region to capture the full value chain from research through to production, with alignment to pandemic preparedness priorities and supply chain resilience goals.

Cross-Cutting and Enabling Opportunities

- The Windsor Framework offers a unique regulatory arbitrage opportunity, enabling Northern Ireland to serve as a bridge for companies seeking simultaneous UK and EU market access for regulated biotechnology products, medical devices, and agricultural innovations. This dual market position, if actively promoted, could become a major attractor for foreign direct investment in engineering biology.
- Substantial ring-fenced UK Government funding for engineering biology through UKRI – which invested £9.1 billion across the UK in 2023–24⁴⁶ – including £100 million dedicated to engineering biology through the Technology Missions Fund,⁴⁷ represents a significant opportunity that Northern Ireland has historically underexploited. With NI currently capturing just 1% of total UKRI investment despite comprising 2.8% of the UK population, a coordinated bidding strategy could yield disproportionate returns from a growing funding base
- All-island collaboration across the 6–7 million population base offers scale advantages for clinical trials, shared research infrastructure, talent pools, and market access. Shared Island funding, Research Ireland mechanisms, and established north–south partnerships provide ready frameworks for expanded collaboration.
- Integration of artificial intelligence and data science with engineering biology applications. Northern Ireland has emerging strengths in digital technology (Kainos, B-Secure) and existing capabilities in bioinformatics that could be applied to accelerate drug discovery, precision agriculture, environmental monitoring, and diagnostics development.

⁴⁶ UK Research and Innovation, *Geographical Distribution of UKRI Funding, Financial Years 2022 to 2023 and 2023 to 2024* (Swindon: UKRI, 2024). Available at: <https://www.ukri.org/publications/2022-to-2023-and-2023-to-2024-geographical-distribution-of-funding/> (Accessed: 26 March 2026).

⁴⁷ UK Research and Innovation, 'New £100m Fund Will Unlock the Potential of Engineering Biology', 9 February 2024. Available at: <https://www.ukri.org/news/new-100m-fund-will-unlock-the-potential-of-engineering-biology/> (Accessed: 26 March 2026).

- The One Health approach—integrating human health, animal health, and environmental health through engineering biology—addresses globally significant challenges including antimicrobial resistance, zoonotic infections, and climate change adaptation. Northern Ireland’s compact scale and cross-sectoral research base make it well-suited to pilot integrated One Health solutions.
- Reshoring and supply chain resilience trends, accelerated by COVID-19 and geopolitical instability, create opportunities for Northern Ireland to develop domestic bioprocessing and biomanufacturing capacity. The region’s existing manufacturing expertise in aerospace and advanced materials could be pivoted towards life sciences manufacturing, including industrial biotech, cleantech, and agritech.

7.4 Threats

Competitive and Sectoral Displacement Threats

- Disruption of existing industries by engineering biology advances developed elsewhere. Advisors emphasised that most engineering biology studies focus only on positive opportunities, but failure to develop capabilities could result in traditional Northern Ireland industries—particularly in agri-food and conventional pharmaceuticals—being displaced by competitors who adopt engineering biology approaches more rapidly. This represents an existential risk to the agri-food sector’s competitiveness.
- Intensifying global competition from regions with substantially greater investment and coordinated national strategies. The United States, China, and Australia are all investing at scales that dwarf Northern Ireland’s capacity, with Australia targeting AUD \$30 billion in annual synthetic biology revenue and 50,000 jobs by 2040. Without focused niche specialisation, Northern Ireland risks irrelevance in the global engineering biology landscape.
- Risk of falling behind other UK regions. None of the six national UKRI engineering biology hubs are led from Northern Ireland, and the Innovate UK Catapult network has no life sciences presence in the region. Other UK cities and regions with established life sciences clusters (London, Cambridge, Edinburgh, Manchester) are attracting disproportionate shares of talent, investment, and infrastructure funding.

Regulatory, Political, and External Threats

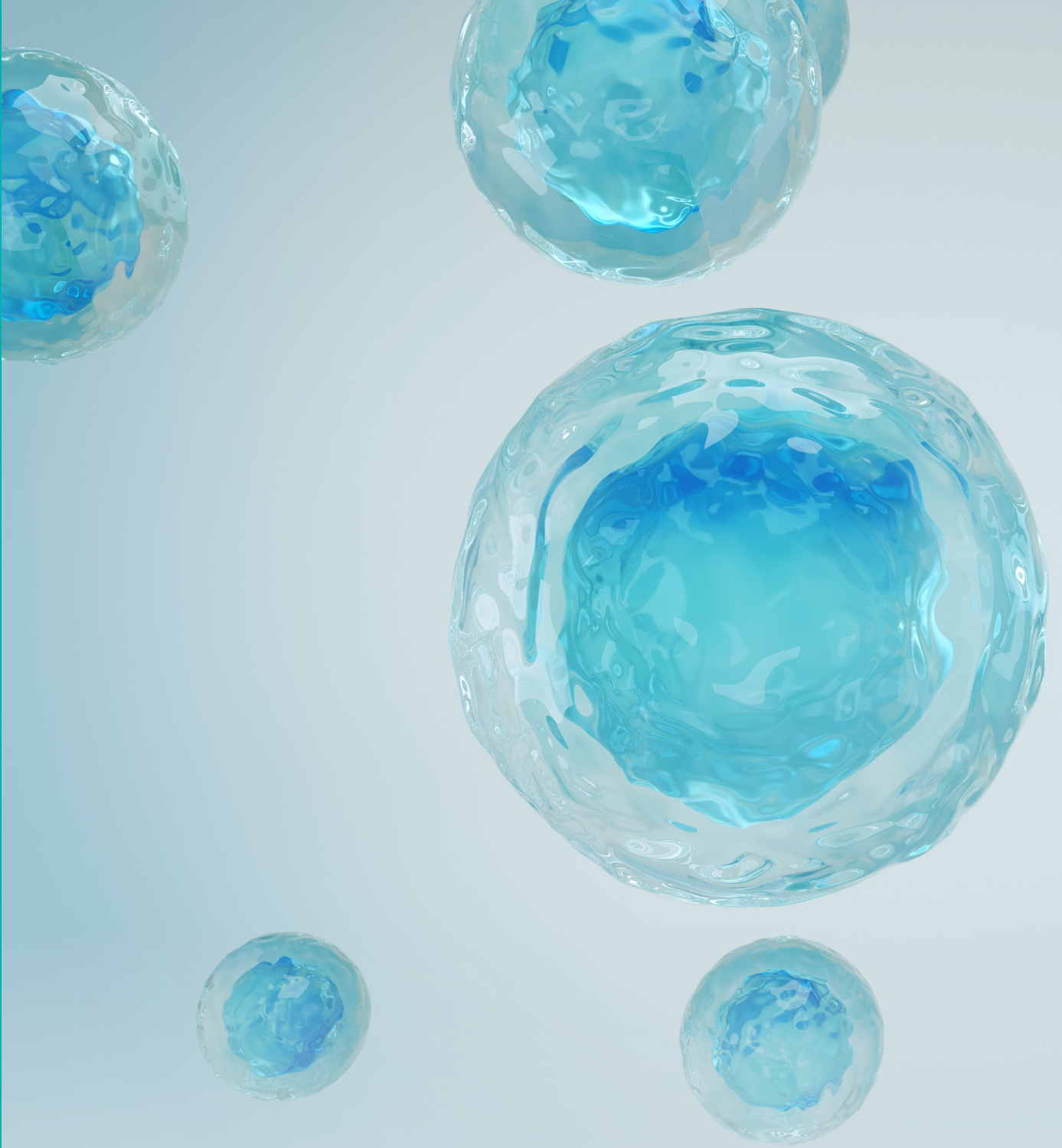
- Windsor Framework complexity and regulatory divergence. While the Framework creates opportunities, it also introduces operational uncertainty. The UK’s Precision Breeding Act 2023 permits gene-edited organisms in England, but Northern Ireland continues to classify these organisms under EU-aligned GMO regulations. This divergence could constrain the development of precision breeding for agri-food locally, creating a competitive disadvantage relative to English counterparts. Ongoing regulatory adjustments create unpredictable compliance burdens for businesses.
- Public perception and acceptance challenges. The ‘Frankenstein food’ narrative around genetically modified organisms remains a significant barrier in agricultural applications, and the Northern Ireland farming community has a culturally cautious disposition around new technologies and data sharing. Workshop participants identified public perception as a key risk to multiple initiatives, requiring sustained public engagement and transparent communication strategies.
- Supply chain vulnerabilities: Northern Ireland’s dependence on imported consumables, reagents, and specialist equipment—predominantly from Chinese sources—was exposed during COVID-19. An estimated 50 per cent of diagnostic supply chains rely on single-source international suppliers, and geopolitical disruption or trade policy changes could severely impact research and production capability.

- The Trump administration's trade and pharmaceutical policies pose an emerging challenge, with potential new pharmaceutical manufacturing incentives in the United States that could redirect foreign direct investment away from European locations, including Northern Ireland. Changes to transatlantic trade arrangements could also affect Northern Ireland's positioning as a manufacturing base for US-bound biopharmaceutical products.
- Climate change and environmental pressures, including the ongoing Lough Neagh crisis and increasing frequency of disease outbreaks such as blue-tongue virus, are placing additional strain on research capacity and diverting resources from strategic development to reactive crisis management.

7.5 Summary

The SWOT analysis reveals that Northern Ireland possesses genuine research strengths, established industry anchors, and a unique strategic position through the Windsor Framework that, collectively, provide a credible foundation for engineering biology development. However, these strengths are constrained by significant infrastructure deficits, skills shortages, fragmented governance, and limited access to scale-up capital. The opportunities are substantial—particularly in food security, diagnostics, environmental remediation, and personalised medicine—but they require coordinated action to overcome the structural weaknesses identified. The threat landscape demands urgency: without proactive investment and strategic focus, Northern Ireland risks not only missing new opportunities but also seeing its existing industrial base disrupted by engineering biology advances developed elsewhere.

The workshop's opportunity-feasibility scoring provides a useful prioritisation lens. Initiatives such as Scale-up Capabilities and Food Security scored highest for opportunity (both 5), whilst Diagnostics and Biosensors scored highest for combined opportunity and feasibility (4/4). The gap between opportunity and feasibility scores across most initiatives—typically scoring 3–5 for opportunity against 2–4 for feasibility—underscores the enabling investment needed to convert recognised opportunities into deliverable outcomes. These findings directly inform the recommendations presented in Chapter 8.



Recommendations and Implementation

Chapter 8: Recommendations and Implementation

This chapter draws together findings from across the study—the strategic landscape roadmap, six topic roadmaps, stakeholder engagements, global landscape insight, and SWOT analysis—to present recommendations structured around three interconnected dimensions: policy recommendations, investment priorities, and future research opportunities.

Northern Ireland possesses genuine strengths in engineering biology, including internationally recognised research, established diagnostic and pharmaceutical companies, dual market access through the Windsor Framework, and a compact geography that enables coordination. However, these are constrained by fragmented governance, a persistent TRL 3–4 gap, limited scale-up infrastructure, skills shortages, and insufficient cross-sector collaboration. The six topic roadmaps should be treated as an integrated portfolio rather than a menu; siloed implementation would negate the synergies that make engineering biology transformative.

8.1 Policy Recommendations

Policy recommendations address the systemic governance and coordination challenges identified across all stakeholder engagement activities. Five priorities are identified, ranging from cross-departmental coordination through regulatory strategy, workforce development, data access, and public engagement. Each is grounded in evidence from the roadmapping process and is designed to create the enabling environment within which investment can be effective.

8.2 Investment Priorities

Investment recommendations target the most impactful areas for resource allocation, informed by the workshop’s opportunity-feasibility scoring. The table below summarises the scoring for each initiative, providing an evidence base for prioritisation.

Table 9: Workshop opportunity-feasibility scoring (1-5 scale)

Initiative	Opp.	Feas.	Key Implication
Food Security & Resilience	5	3	Highest opportunity; TRL 3–4 gap and cluster mapping needed
Scale-Up Capabilities	5	3	Known customer pull; infrastructure investment required
Circular Bioeconomy	4	3	Lough Neagh as flagship demonstrator opportunity
Agri-Tech Innovation	4	2	Lowest feasibility due to agricultural data access barriers
Diagnostics & Biosensors	4	4	Strongest combined score; most immediately actionable
One Health	3	3	Strategically important; requires cross-sector steering group

Based on this scoring, combined with cross-cutting analysis and international comparator evidence, five investment priorities are recommended: shared engineering biology infrastructure, a TRL 3–4 bridging fund, a diagnostics and biosensors accelerator, a Lough Neagh circular bioeconomy demonstrator, and a coordinated approach to UK-wide and international funding.

8.3 Future Research Opportunities

Seven research opportunities were identified as areas requiring deeper investigation beyond the scope of the current study. These represent areas where Northern Ireland could develop distinctive capabilities or where emerging trends create windows of opportunity requiring timely action: advanced cell and gene therapy manufacturing; agricultural microbiome engineering; bio-based packaging and materials; digital twins and AI for bioprocess optimisation; One Health surveillance and biosecurity; all-island engineering biology collaboration; and a disruptive impact assessment of threats to existing NI industries.

8.4 Summary of Recommendations, Actions and Expected Impact

Table 8.2 summarises all recommendations, identifying lead responsibility, indicative timeframe, and expected strategic impact. Impact statements are qualitative and reflect strategic outcomes from the roadmapping process. Quantified economic impact (e.g. job creation, GVA) would require a dedicated impact assessment exercise.

Table 10: Summary of recommendations, actions, and expected strategic impact

#	Recommendation / Action	Lead	Phase	Expected Strategic Impact
8.1 Policy Recommendations				
P1	Establish Cross-Departmental Engineering Biology Coordination Body Formal representation from DfE, DAERA, DoH, Invest NI, QUB, UU, AFBI, and industry. Dedicated secretariat; reports to Matrix.	DfE / Matrix	Phase 1	Resolves fragmented governance identified as the primary barrier. Enables coordinated strategy, aligned funding, and harmonised definitions. Without this, all other recommendations risk being undermined.
P2	Harmonise Regulatory Frameworks and Leverage the Windsor Framework Regulatory advisory service for dual UK/EU navigation; regulatory sandbox for low-risk agri/environmental innovations.	DfE, DAERA, Invest NI	Phase 1-2	Converts NI's dual market position into a competitive advantage. Enables simultaneous UK/EU clinical trials and product approvals. Addresses precision breeding constraints for agri-food.
P3	Develop Strategic Skills and Workforce Policy Workforce strategy: doctoral training, apprenticeships, industry-academic secondments, CPD. Expand QUB MSc, co-funded PhDs, KTPs.	DfE, QUB, UU, industry	Phase 1-2	Addresses the universal skills gap. Builds the interdisciplinary workforce at the biology-data science intersection. Reduces brain drain by creating visible career pathways.
P4	Create an Integrated Data Strategy NI engineering biology data strategy: farm-level, health, environmental, and supply chain data. Secure platform with all-island dimension.	DAERA, DfE, AICC	Phase 1-2	Unlocks the binary go/no-go on Agri-Tech (feasibility 2/5 – lowest). Without agricultural data access, a major strategic pillar fails. Enables One Health and diagnostics data sharing.
P5	Strengthen Public Engagement and Awareness Sustained programme using NI case studies (Lough Neagh, methane reduction). Target public and policymakers.	Matrix / Coordination Body, QUB, UU	Phase 2-3	Overcomes public perception barriers around synthetic biology and gene editing. Builds social licence for engineering biology adoption in agriculture and environment.
8.2 Investment Priorities				
I1	Shared Engineering Biology Infrastructure ("Research Hotel") Fermentation capacity, cell-free systems, flexible lab space, analytical equipment. Multi-sector. Partnered with UK Catapult (CPI). Permanent CGTC/MDC staff.	Invest NI / DfE, QUB, UU	Phase 2	Addresses the most impactful infrastructure gap. NI companies are losing business due to lack of scale-up capability. Bridges the Catapult deficit and creates critical mass for ecosystem development.
I2	TRL 3-4 Bridging Fund Dedicated mechanism targeting the valley of death. Cross-departmental governance; department-agnostic access.	DfE / Invest NI	Phase 2	Directly tackles the most pervasive barrier across all six initiatives. Without TRL 3-4 bridging, NI will continue generating knowledge commercialised elsewhere.
I3	Diagnostics and Biosensors Accelerator Programme Diagnostics Forum (HIRANI-led), training schools (QUB/UU/AFBI), capability mapping, structured accelerator. Platform funding approach.	HIRANI / Invest NI, QUB, UU, AFBI	Phase 1-2	Capitalises on NI's strongest combined opportunity-feasibility score (4/4). Most immediately actionable initiative aligned with DfE/Invest NI priorities and NHS Reset Plan.
I4	Lough Neagh Circular Bioeconomy Demonstrator Flagship project: algae harvesting, biopolymer creation, modular biorefinery proof-of-concept.	DAERA / QUB, AFBI	Phase 2	Creates a high-profile flagship demonstrating engineering biology's practical value. Addresses NI's most pressing environmental crisis. Develops a potentially exportable remediation model.
I5	Leverage UK-Wide and International Funding Dedicated funding advisory; demystify Innovate UK/UKRI processes; coordinated NI applications.	Invest NI / DfE, QUB, UU	Phase 1-4	Corrects NI's historic underperformance in competitive UK funding. UKRI is ring-fencing significant engineering biology budgets – a time-limited window.
8.3 Future Research Opportunities				
R1	Advanced Cell and Gene Therapy Manufacturing Feasibility study for NI as cell therapy clinical trial hub. Leverage IMPACT programme, Windsor Framework, NI Biobank, RVH cell pharmacy.	QUB / DoH, FMI	Phase 2-3	Positions NI uniquely as the only UK location able to run dual UK/EU clinical trials simultaneously. Leverages the €100m+ all-island IMPACT programme.
R2	Agricultural Microbiome Engineering Rumen microbiome for methane reduction, soil microbiome for crop productivity, microbiome-based biocontrol.	AFBI / QUB, DAERA	Phase 2-3	Directly contributes to NI's Net Zero targets for the livestock sector. Leverages existing AFBI/QUB rumen research strengths.
R3	Bio-Based Packaging and Materials Feasibility study linking agricultural waste streams to biopolymer production. Connects to Circular Bioeconomy roadmap.	QUB / UU, Invest NI	Phase 2-3	Addresses NI's proportionally large food sector's packaging dependency. Creates new value chains from agricultural waste.
R4	Digital Twins and AI for Bioprocess Optimisation Cross-sectoral programme: AI/digital twins for bioprocess, predictive modelling, AI-driven drug formulation.	QUB / UU, AICC	Phase 2-3	Leverages NI's data science and cybersecurity strengths as a distinctive competitive advantage. Cross-sectoral application maximises return.
R5	One Health Surveillance and Biosecurity Integrated platform combining biosensors, genomic sequencing, and wastewater monitoring with data science.	QUB / AFBI, DoH, DAERA	Phase 2-3	Exploits NI's compact geography as a living laboratory for integrated surveillance. Creates a potentially exportable model.
R6	All-Island Engineering Biology Collaboration Comprehensive mapping of capabilities, complementarities, shared infrastructure, joint funding, and strategic alignment.	Matrix / DfE, Research Ireland	Phase 2-3	Leverages Shared Island Fund and IMPACT model. Expands effective scale through ROI complementarities.
R7	Disruptive Impact Assessment Assessment of which NI sectors are most vulnerable to displacement by engineering biology innovations developed elsewhere.	Matrix / DfE, Invest NI	Phase 1-2	Provides the missing defensive analysis. Creates urgency by showing what NI risks losing, not just what it could gain.

8.5 Implementation Framework

A phased implementation approach is proposed, recognising that foundational elements must be established before subsequent activities can succeed. The phasing below is indicative; precise timelines should be determined by the responsible departments in light of budgetary cycles, capacity, and political priorities.

Table 11: Phased implementation framework

Phase	Time-frame	Key Actions	Key Outcomes
Phase 1 Foundation	0–12 months	Establish Coordination Body and policy coordination group. Launch skills programmes and commission data strategy. Prepare foundational UKRI/ Innovate UK bids. Establish Diagnostics Forum. Begin disruptive impact assessment. Map engineering biology cluster.	Cross-departmental governance operational. Engineering biology cluster mapped. PhD/MSc pipeline initiated. Data strategy commissioned. Major funding bids submitted.
Phase 2 Capability Building	12–36 months	Build shared infrastructure ('research hotel'). Establish data platform. Launch TRL 3–4 bridging fund. Implement diagnostics accelerator. Begin Lough Neagh demonstrator. Pilot One Health surveillance. Pursue all-island partnerships. Commission cell therapy feasibility study.	Scale-up capacity becoming operational. First accelerator cohort through. Agricultural data platform piloted. Bioremediation proof-of-concept delivered. One Health steering group established.
Phase 3 Scale & Integration	3–5 years	Scale successful pilots to commercial deployment. Expand commercial deployment support. Attract additional companies and researchers. Pursue international partnerships. Launch public engagement at scale.	Innovations moving to market. International reputation emerging. Private sector co-investment increasing. Export of expertise and toolkits beginning.
Phase 4 Cluster Maturity	5+ years	Self-sustaining ecosystem operating. Active international positioning of NI as engineering biology hub. Export development for technologies and approaches. Continuing strategy evolution.	Engineering biology cluster operating sustainably. Established global reputation in niche areas. Revenue from exported technologies. Next-generation strategy development.

Critical Path

Certain elements are critical to overall success—failure in any of these would jeopardise multiple initiatives across the portfolio:

- Data access for Agri-Tech:** This is a binary go/no-go decision point, as stated explicitly by the workshop team.
- Policy coordination:** Enabling cross-departmental funding and regulatory harmonisation affects all initiatives.
- TRL 3–4 infrastructure:** This determines whether research excellence translates to commercial impact across all sectors within Northern Ireland.
- Skills pipeline:** Without adequate talent and career pathways, all initiatives will struggle to materialise, regardless of other investments.
- Anchor tenant engagement:** Participation of established companies in shared infrastructure provides credibility, guaranteed utilisation, and signals viability to other stakeholders.

8.6 Concluding Remarks

The recommendations are designed to be mutually reinforcing. Policy coordination creates the governance environment within which investment can be effective. Investment in shared infrastructure addresses the valley of death that policy reform alone cannot bridge. Future research opportunities ensure that Northern Ireland positions itself at the frontier of emerging applications rather than merely catching up.

Northern Ireland's small scale, often perceived as a limitation, becomes a genuine advantage when leveraged strategically. The living laboratory approach—developing, testing, and validating innovations across an integrated system spanning agriculture, environment, and health—is practical at Northern Ireland's scale. The current moment represents a window of opportunity: UKRI is ring-fencing significant engineering biology funding, the global bioeconomy is expanding rapidly, and the Windsor Framework creates advantages no other UK region can replicate. The question is not whether engineering biology will be important, but whether Northern Ireland will be a contributor to or merely a consumer of the innovations it produces.



Annexes

Annex I: NI Research Capacity by Application Area

Supporting data compiled in response to the Steering Group feedback requesting quantitative evidence on the number and nature of researchers, infrastructure and companies active in each of the priority application areas identified by interviewees. Data sourced from publicly available institutional and government sources.

Healthcare and Medicine

Application Area	Key NI Researchers / Groups	Infrastructure & Investment	Companies Active
Advanced cell therapy / CAR-T	Patrick G Johnston Centre for Cancer Research, QUB (Prof Chris Scott) ⁴⁸ Wellcome-Wolfson Institute for Experimental Medicine (Prof Ultan Power)	£55m Future Medicines Institute (FMI); £35m NI Executive + £20m industry consortium ⁴⁹ Shared laboratory at QUB for industry-academia collaboration	FMI consortium: Diaceutics, Fusion Antibodies, Randox, Almac, Sonrai Analytics, Exploristics, ProAxis ⁵⁰
Precision medicine & diagnostics	Precision Medicine Centre (PMC) at QUB – 563m ² integrated lab; £2m+ in genomics, digital pathology, automation ⁵¹ 17+ research centres; 1,000+ researchers region-wide ⁵²	19,000+ students and 5,600 graduates annually in health/life sciences ⁵³ PMC co-investment: Invest NI, QUB, Public Health Agency	250+ life/health sciences companies; 18,000 employees; exports to 140+ countries ⁵⁴ Key: Almac Diagnostics, Randox, Diaceutics, Sonrai, Fusion Antibodies ⁵⁵
Antibody engineering & drug delivery	Fusion Antibodies plc (AIM: FAB) – 200+ humanisation projects; ≥½ entered clinical trials ⁵⁶ QUB School of Pharmacy – microneedle delivery, biomaterials, wound repair ⁵⁷	£808k Innovate-UK Launchpad grant (2025) for Fusion-QUB cancer antibody ⁵⁸ FMI access to shared facilities and £5m core equipment	Fusion Antibodies plc; Almac Group (antibody drug conjugates)
Bacteriophage applications	QUB IGFS ASSET Centre – Cat. 2 & 3 cell culture for phage protein and monoclonal antibody production ⁵⁹ Prof Brendan Gilmore (QUB Pharmacy) – infection and AMR research ⁶⁰	IGFS: €60m+ invested since 2015; ~70 academics, ~70 post-docs, 100+ PGR students ⁶¹	Emerging area – primarily university-based

48 Queen's University Belfast (2024) 'Johnston Cancer Research Centre'. Available at: <https://www.qub.ac.uk/research-centres/cancer-research/> (Accessed: 26 March 2026).

49 Queen's University Belfast (2024) 'Murphy announces £55m investment in the Future Medicines Institute'. Available at: <https://www.qub.ac.uk/News/Allnews/2024/murphy-announces-investment-future-medicines-institute.html> (Accessed: 26 March 2026).

50 Health Innovation Research Alliance NI (2024) 'Future Medicines Institute Launched'. Available at: <https://hira-ni.com/future-medicines-institute-launched/> (Accessed: 26 March 2026).

51 Queen's University Belfast (n.d.) 'Precision Medicine Centre'. Available at: <https://www.qub.ac.uk/research-centres/PMC/> (Accessed: 26 March 2026).

52 Invest Northern Ireland (n.d.) 'Precision biomarkers and diagnostics in Northern Ireland'. Available at: <https://www.great.gov.uk/international/content/investment/opportunities/precision-medicine-biomarkers-and-diagnostics-in-northern-ireland/> (Accessed: 26 March 2026).

53 Invest Northern Ireland (n.d.) 'Precision biomarkers and diagnostics in Northern Ireland'. Available at: <https://www.great.gov.uk/international/content/investment/opportunities/precision-medicine-biomarkers-and-diagnostics-in-northern-ireland/> (Accessed: 26 March 2026).

54 Invest Northern Ireland (n.d.) 'Life and health sciences'. Available at: <https://www.investni.com/international-business/our-sectors/life-and-health-sciences> (Accessed: 26 March 2026).

55 Invest Northern Ireland (n.d.) 'Almac case study'. Available at: <https://www.investni.com/international-business/case-studies/almac> (Accessed: 26 March 2026).

56 Fusion Antibodies (n.d.) 'Events archives – 200th Antibody Humanisation'. Available at: <https://fusionantibodies.com/news/category/events/> (Accessed: 26 March 2026).

57 Queen's University Belfast (n.d.) 'Microneedle delivery systems for next-generation antibody therapeutics'. Available at: <https://www.qub.ac.uk/courses/postgraduate-research/> (Accessed: 26 March 2026).

58 Irish News (2025) '£800,000 grant will boost Fusion project to develop new cancer antibody', 24 April. Available at: <https://www.irishnews.com/news/business/> (Accessed: 26 March 2026).

59 Queen's University Belfast (n.d.) 'Biosensor Technologies – IGFS'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteForGlobalFoodSecurity/FacilitiesIncludingASSETlab/BiosensorTechnologies/> (Accessed: 26 March 2026).

60 Queen's University Belfast (2021) 'Queen's scientists awarded significant funding to develop the enzymes of tomorrow'. Available at: <https://www.qub.ac.uk/News/Allnews/2021/> (Accessed: 26 March 2026).

61 Monplas.eu (n.d.) 'IGFS – QUB'. Available at: <https://monplas.eu/igfs> (Accessed: 26 March 2026).

Agri-Food and Environment

Application Area	Key NI Researchers / Groups	Infrastructure & Investment	Companies Active
Rumen microbiome / methane reduction	Prof Sharon Huws (QUB) – £10m+ funding over 5 years; 150+ publications; led global Rumen Microbial Genomics network (2013–2023); leads RUMEN Gateway project (16 partners) ⁶² QUB–AFBI: €2m Seasolution project (seaweed and methane) ⁶³ QUB IGFS leads BBSRC-funded willow/agroforestry methane research with AFBI and Reading Univ. ⁶⁴	£39m IGFS facility (12,000m ² , 2019); 500 research staff and students ⁶⁵ £59m research income at IGFS over past 7 years ⁶⁶	Agri-Food Quest members incl. Dale Farm, Lakeland Dairies, Linden Foods, AgriSearch, Hewitt Meats ⁶⁷ AFBI (statutory body)
Precision breeding	IGFS: 1st in UK in REF for Agriculture, Veterinary and Food Science (94% world-leading or internationally excellent) QUB–AFBI Strategic Alliance for sustainable agri-food research ⁶⁸	Agri-Food Quest Competence Centre: links 30+ NI agri-food firms with QUB, UU, AFBI ⁶⁹	30+ agri-food firms via Agri-Food Quest; CAFRE (DAERA training body) ⁷⁰
Biosensors & food traceability	Dr Katrina Campbell (QUB) – world-leading biosensor research; optical, electrochemical and nanosensing platforms ⁷¹ ASSET Centre: IAEA Collaborating Centre; DEFRA Centre of Expertise; Centre for Excellence in Agriculture and Food Integrity with UK National Measurement Lab ⁷²	~£10m ASSET analytical chemistry/mass spectrometry; ~£2.5m biosensor and proteomic facilities ⁷³ AgriPlas – first cold-plasma antimicrobial facility of its kind in Europe	Randox (food diagnostics); EIT Food consortium partners; ABP Food Group, PepsiCo, Waitrose (via EIT) ⁷⁴
Bio-based packaging	QUB and AMIC – polymers and thin film development R&D No specific researcher count publicly available for this niche	AMIC (Belfast Region City Deal)	

62 British Society of Animal Science (n.d.) 'Ruminant Methane Mitigation Conference' booklet. Prof Sharon Huws profile. Available at: https://www.bisas.org.uk/assets/files/Methane_Event_Booklet.pdf (Accessed: 26 March 2026).

63 Agriland (2021) 'Irish farm trials to investigate how seaweed could lower livestock emissions', 1 June. Available at: <https://www.agriland.ie/farming-news/> (Accessed: 26 March 2026).

64 Agriland (2021) 'NI farm trials to test willow's ability to reduce methane emissions', 6 October. Available at: <https://www.agriland.co.uk/farming-news/> (Accessed: 26 March 2026).

65 Queen's University Belfast (n.d.) 'IGFS - Facilities'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/FacilitiesincludingASSETlab/> (Accessed: 26 March 2026).

66 Queen's University Belfast (n.d.) 'IGFS Research Environment'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/research/ResearchEnvironment/> (Accessed: 26 March 2026).

67 Queen's University Belfast (n.d.) 'IGFS Partnerships including EIT Food - Agri-Food Quest'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/PartnershipsincludingEITFood/> (Accessed: 26 March 2026).

68 Queen's University Belfast (n.d.) 'IGFS Partnerships'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/PartnershipsincludingEITFood/> (Accessed: 26 March 2026).

69 Queen's University Belfast (n.d.) 'IGFS Partnerships'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/PartnershipsincludingEITFood/> (Accessed: 26 March 2026).

70 Queen's University Belfast (n.d.) 'IGFS Partnerships including EIT Food - Agri-Food Quest'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/PartnershipsincludingEITFood/> (Accessed: 26 March 2026).

71 Queen's University Belfast (n.d.) 'Biosensor Technologies - IGFS'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/FacilitiesincludingASSETlab/BiosensorTechnologies/> (Accessed: 26 March 2026).

72 Queen's University Belfast (n.d.) 'IGFS - Facilities'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/FacilitiesincludingASSETlab/> (Accessed: 26 March 2026).

73 Queen's University Belfast (n.d.) 'IGFS Research Environment'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/research/ResearchEnvironment/> (Accessed: 26 March 2026).

74 Queen's University Belfast (n.d.) 'IGFS Partnerships including EIT Food - Agri-Food Quest'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteforGlobalFoodSecurity/PartnershipsincludingEITFood/> (Accessed: 26 March 2026).

Industrial Biotechnology

Application Area	Key NI Researchers / Groups	Infrastructure & Investment	Companies Active
Biocatalysis & enzyme engineering	Multi-disciplinary QUB team: Prof Chris Allen and Dr Chris Law (Biological Sciences), Dr Meilan Huang (Chemistry), Prof Brendan Gilmore (Pharmacy) ⁷⁵ Developed INSIGHT™ platform (metagenomics + computational chemistry + gene mining) Dr Meilan Huang: £2.2m+ in enzyme discovery grants; BBSRC-funded BioAID DTP for AI-driven enzyme design ⁷⁶	Almac Group: \$7m investment in biocatalysis R&D with QUB (2015), supported by Invest NI ⁷⁷ Further £2m from Invest NI (ERDF-funded) for INSIGHT™ platform; two prior rounds completed ⁷⁸	Almac Sciences (Dept. of Biocatalysis and Isotope Chemistry, Craigavon) – global biocatalysis services ⁷⁹
Sustainable materials (natural fibre composites)	QUB and AMIC: polymers and thin film development through Belfast Region City Deal Emerging cross-disciplinary area; no NI-specific researcher count publicly available	AMIC (Belfast Region City Deal) – advanced manufacturing capabilities Anaerobic digestion leveraging existing NI engineering strengths	Emerging area – AMIC-linked advanced manufacturing companies

75 Queen's University Belfast (2021) 'Queen's scientists awarded significant funding to develop the enzymes of tomorrow'. Available at: <https://www.qub.ac.uk/News/Allnews/2021/> (Accessed: 26 March 2026).

76 Huang, M. (n.d.) QUB Pure Profile. Grants listing incl. BioAID DTP. Available at: <https://pure.qub.ac.uk/en/persons/meilan-huang/> (Accessed: 26 March 2026).

77 Almac Group (2015) 'Almac Group drives biocatalysis leadership with a further \$7M investment'. Available at: <https://www.almacgroup.com/news/almac-group-drives-biocatalysis-leadership-7m-investment/> (Accessed: 26 March 2026).

78 Almac Group (2021) 'Almac awarded £multimillion R&D grant - INSIGHT™'. Available at: <https://www.almacgroup.com/news/> (Accessed: 26 March 2026).

79 Almac Group (n.d.) 'Biocatalysis services'. Available at: <https://www.almacgroup.com/services/almac-sciences/biocatalysis/> (Accessed: 26 March 2026).

Environmental Solutions

Application Area	Key NI Researchers / Groups	Infrastructure & Investment	Companies Active
Lough Neagh bioremediation	<p>QUB multidisciplinary team (School of Biological Sciences + IGFS):⁸⁰ Dr Neil Reid – ecology/genomics; Nature correspondence (2023) Prof Katrina Campbell – rapid diagnostics for cyanobacteria/toxins Prof Lisa Connolly – water monitoring pilot with NI Water Prof Mark Emmerson – Co-Centre for Climate, Biodiversity and Water Prof Jamie Dick – invasive species impacting ecology Dr Deepak Kumaresan – phosphorus influx and aquatic microbes Prof John McGrath – DNA sequencing of algal components</p>	<p>Lough Neagh: UK's largest freshwater lake; supplies 40%+ of NI's drinking water; drains ~40% of NI landmass⁸¹ QUB collaborating with AFBI, DAERA, and NI Water Research published in Environment International; Nature (2023)</p>	<p>Northern Ireland Water (statutory partner); AFBI (statutory research body); DAERA (govt. dept.)⁸² Primarily public-sector led; commercial applications emerging</p>
Novel biomaterials for construction	<p>QUB biochar-concrete project (Dr Sadish Oumabady & Dr Rory Doherty) – industry-led collaboration funded through the Centre for Advanced Sustainable Energy (CASE)⁸³. CASE is a partnership between QUB, Ulster University, and AFBI at the forefront of NI's circular bioeconomy and decarbonisation research⁸⁴. QUB also an academic partner in the Holcim UK/Canary Wharf net-zero concrete trials (with Univ. of Cambridge, Skanska, Arup) – achieving negative-carbon concrete (-14 kgCO₂e/m³)⁸⁵</p>	<p>Biochar from AD digestate: NI currently produces 110kt digestate dry matter yielding ~32kt biochar; projected 184kt annually under UK CCC 2050 biomethane target⁸⁶ Lab tests show self-repair capabilities and early strength attainment; factory trials completed with industry partner on optimised mixes for roof tiles, paving, facades, curbing Emission reductions of up to 75% vs conventional concrete; construction sector in NI emits up to 900kt CO₂e</p>	<p>Industry partners: Mannok Build, Breedon Group, Irish Cements, Northstone NI, United Renewables, Mineral Products Association NI⁸⁷ Holcim UK (Canary Wharf trials with QUB monitoring)</p>

80 Queen's University Belfast (2025) 'Reviving Lough Neagh: Combating Toxic Algal Blooms'. Available at: <https://www.qub.ac.uk/Research/case-studies/reviving-lough-neagh.html> (Accessed: 26 March 2026).

81 Queen's University Belfast (2024) 'Queen's research details the public health risks of Lough Neagh'. Environment International. Available at: <https://www.qub.ac.uk/News/Allnews/featured-research/> (Accessed: 26 March 2026).

82 Queen's University Belfast (2025) 'Reviving Lough Neagh: Combating Toxic Algal Blooms'. Available at: <https://www.qub.ac.uk/Research/case-studies/reviving-lough-neagh.html> (Accessed: 26 March 2026).

83 Oumabady, S. and Doherty, R. (2025) 'Using waste-derived materials to produce sustainable concrete', Circular Online, 25 March. Available at: <https://www.circularonline.co.uk/case-studies/using-waste-derived-materials-to-produce-sustainable-concrete/> (Accessed: 26 March 2026).

84 Energy Ireland (2025) 'Building bridges: Innovating to keep the lights on – CASE'. Available at: <https://www.energyireland.ie/building-bridges-innovating-to-keep-the-lights-on/> (Accessed: 26 March 2026).

85 ESG News (2026) 'Holcim UK Delivers Net Zero Concrete Using Carbon Storing Biochar', March. Available at: <https://esgnews.com/holcim-uk-delivers-net-zero-concrete-using-carbon-storing-biochar/> (Accessed: 26 March 2026).

86 CASE Research, *Opportunities for Atmospheric CO₂ Removal in Northern Ireland Using Biochar* (Belfast: CASE Research, 2025). Available at: [https://case-research.net/wp-content/uploads/2025/08/Opportunities-for-atmospheric-CO₂-removal-NI-using-Biochar-final.pdf](https://case-research.net/wp-content/uploads/2025/08/Opportunities-for-atmospheric-CO2-removal-NI-using-Biochar-final.pdf) (Accessed: 26 March 2026).

87 Queen's University Belfast and Centre for Advanced Sustainable Energy, 'Using Waste-Derived Materials to Produce Sustainable Concrete', *Circular Online*, 25 March 2025. Available at: <https://www.circularonline.co.uk/case-studies/using-waste-derived-materials-to-produce-sustainable-concrete/> (Accessed: 26 March 2026).

Headline NI-Wide Statistics

Indicator	Data
Life and health sciences companies	250+ businesses employing 18,000 people, exporting to 140+ countries ⁸⁸
Research centres and researchers	18 world-leading research centres; 1,000+ researchers; QUB and UU rank Top 10 in UK for bioscience research ⁸⁹
Industrial output	£2.4bn industrial output; supports 15,000+ additional jobs in NI economy ⁸⁹
Skills pipeline	19,000+ students studying and 5,600 graduating annually in health and life sciences ⁹⁰
Future Medicines Institute	£55m investment (£35m NI Executive + £20m industry); 7-company consortium; UKRI Strength in Places Fund ⁹¹
IGFS research income	£59m over 7 years; €60m+ total investment since 2015; ~70 academics, ~70 post-docs, 100+ PGR students ⁹²
Biocatalysis investment	\$7m+ Almac-QUB R&D programme; £2m Invest NI ERDF support for INSIGHT™; three rounds ⁹³
Pharmaceuticals exports	3rd most exported product from NI (£500m, 2020); one of top 10 most traded items globally ⁹⁴

88 Invest Northern Ireland (n.d.) 'Life and health sciences'. Available at: <https://www.investni.com/international-business/our-sectors/life-and-health-sciences> (Accessed: 26 March 2026).

89 ABPI (2022) 'Northern Ireland life sciences sector continues strong economic output', May. Available at: <https://www.abpi.org.uk/media/news/2022/may/> (Accessed: 26 March 2026).

90 Invest Northern Ireland (n.d.) 'Precision biomarkers and diagnostics in Northern Ireland'. Available at: <https://www.great.gov.uk/international/content/investment/opportunities/precision-medicine-biomarkers-and-diagnostics-in-northern-ireland/> (Accessed: 26 March 2026).

91 Queen's University Belfast (2024) 'Murphy announces £55m investment in the Future Medicines Institute'. Available at: <https://www.qub.ac.uk/News/Allnews/2024/murphy-announces-investment-future-medicines-institute.html> (Accessed: 26 March 2026).

92 Queen's University Belfast (n.d.) 'IGFS Research Environment'. Available at: <https://www.qub.ac.uk/Research/GRI/TheInstituteForGlobalFoodSecurity/research/ResearchEnvironment/> (Accessed: 26 March 2026).

93 Almac Group (2015) 'Almac Group drives biocatalysis leadership with a further \$7M investment'. Available at: <https://www.almacgroup.com/news/almac-group-drives-biocatalysis-leadership-7m-investment/> (Accessed: 26 March 2026).

94 ABPI (2022) 'Northern Ireland life sciences sector continues strong economic output', May. Available at: <https://www.abpi.org.uk/media/news/2022/may/> (Accessed: 26 March 2026).

Annex II: Landscape tables

First Table: Layer A – Trends and Drivers: Cluster Inventory

Sub-layer	Code	Cluster	Statements
A1 – Market Drivers (Economics and Strategic)	A1.1	Global bioeconomy markets reaching \$2.2 trillion by 2040 with accelerating corporate investment	14
	A1.2	Healthcare markets expanding for personalised therapeutics, cell therapies, and precision diagnostics	20
	A1.3	Corporate sustainability targets and supply chain resilience driving demand for bio-based solutions	21
	A1.4	Falling technology costs and AI integration lowering barriers to market entry	13
	A1.5	City Deals and Windsor Framework to capture value from its life sciences base	47
	A1.6	Agri-Food Sector Economic Significance (NEW)	1
A2 – Policy & Regulations	A2.1	Regulatory complexity and EU-UK divergence creating both compliance burdens and innovation opportunities	23
	A2.2	Windsor Framework dual market access remains under-exploited despite strategic potential	13
	A2.3	Net zero legislation and climate targets compelling adoption of engineering biology solutions	25
	A2.4	Fragmented governance and geopolitical shifts require coordinated cross-departmental leadership	39
	A2.5	UK Industrial Policy and Strategic Alignment (NEW)	6
	A2.6	Regulatory (NEW)	3
A3 – Social, Technology and Environment	A3.1	AI and digital technologies accelerating R&D and enabling precision biology applications	14
	A3.2	Climate change impacts on agriculture, health and water driving demand for biological solutions	26
	A3.3	Food security and supply chain resilience demanding domestic manufacturing capability	21
	A3.4	Antimicrobial resistance and One Health creating cross-sector intervention opportunities	16
	A3.5	Public perception and biosecurity concerns requiring trust-building and responsible innovation	9
	A3.6	Brain drain and skills gaps constraining sector growth despite strong societal need alignment	40
	A3.7	Clean Energy (NEW)	3
A4 – Competitive Context	A4.1	UK biotech research leadership but scale-up gap threatens international competitiveness	13
	A4.2	Precision medicine and diagnostics as established NI strengths needing better coordination	14
	A4.3	Windsor Framework dual market access creating unique regulatory and commercial advantage	10
	A4.4	Funding access and industry-academia collaboration lagging behind other UK regions	17
	A4.5	Skills deficit, brain drain and fragmented leadership constraining competitiveness	42
	A4.6	Grants and Funding (NEW)	1

Note: Yellow-highlighted rows with (NEW) indicate clusters added during the workshop.

Second Table: Layer B – Applications, Capabilities, Products and Services: Cluster Inventory

Sub-layer	Code	Cluster	Statements
B1 – Healthcare & Medicine	B1.1	Cell and gene therapy expanding beyond oncology requiring local treatment capacity	13
	B1.2	Precision medicine as established NI strength requiring hub/Catapult connectivity	18
	B1.3	AI-driven drug discovery and digital health platforms accelerating development	17
	B1.4	Diagnostics and biosensors requiring domestic manufacturing capability restoration	15
	B1.5	mRNA therapeutics and biomanufacturing scale-up leveraging CDMO capabilities	8
	B1.6	Microbiome therapeutics and antimicrobials addressing resistance challenges	17
	B1.7	Clinical academic capacity gap constraining research leadership and trials	12
	B1.8	Strategic specialisation needed to differentiate from established UK centres	21
	B1.9	Mental health pharmaceuticals and healthy ageing as emerging growth areas	18
	B1.10	QUB, UU, a large biotech firm and Randox anchoring integrated life sciences ecosystem	66
B2 – Agri-Food & Environment	B2.1	Precision breeding and gene editing for crop resilience and competitiveness	10
	B2.2	Livestock genetics and animal engineering for disease resistance and emissions	10
	B2.3	Methane reduction and low-emissions livestock through microbiome manipulation	7
	B2.4	Fermentation technologies for alternative proteins and biomaterials	8
	B2.5	Food security and supply chain resilience requiring local production capability	9
	B2.6	Vertical farming and controlled environment agriculture on brownfield sites	3
	B2.7	Agricultural-tech sector disconnect requiring better innovation policy alignment	11
	B2.8	AFBI and universities anchoring world-class agri-food research ecosystem	27
B3 – Industrial Biotechnology	B3.1	Missing CPI-type bioengineering facility limiting scale-up and Catapult connectivity	20
	B3.2	Lost manufacturing capability for antibodies, primers and recombinant proteins	10
	B3.3	Domestic biomanufacturing for pandemic preparedness and supply chain security	10
	B3.4	Biocatalysis and enzyme engineering for sustainable pharmaceutical manufacturing	14
	B3.5	Bio-based materials and sustainable aviation fuels for decarbonisation	9
	B3.6	Shared manufacturing facility enabling valley-of-death crossing for SMEs	19

Sub-layer	Code	Cluster	Statements
B4 - Environmental Solutions	B4.1	Bioremediation and water quality solutions addressing Lough Neagh challenges	10
	B4.2	Circular bioeconomy replacing fossil feedstocks with bio-based materials	11
	B4.3	Biofuels and green biorefineries for decarbonisation and net zero targets	6
	B4.4	Carbon capture through biogenic CO ₂ sequestration from biomass processes	3
	B4.5	Engineered microbial biofertilisers and ammonia emission reduction	4
B5 - Cross-Sector Initiatives	B5.1	Healthcare, Medicine and Farm Animal Health (NEW)	1
	B5.2	One Health Approach - Cross-Sector (NEW)	1
	B5.3	Endemic Disease - Diagnostics and Interventions (NEW)	0
	B5.4	Collaboration through Future Medicine Institute (NEW)	0
	B5.5	AMIC Labs incubating sensor manufacturing capabilities (NEW)	1

Note: Yellow-highlighted rows with (NEW) indicate clusters added during the workshop.

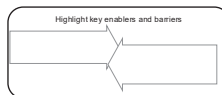
Third Table: Layer C – Resources, Technologies and Enablers: Cluster Inventory

Sub-layer	Code	Cluster	Statements
C1 – Technology Platforms	C1-1	Biofoundries and Automation: Automated Design-Build-Test-Learn infrastructure	18
	C1-2	Biomanufacturing Platforms: Scale-up and production infrastructure	6
	C1-3	Regional Infrastructure Gaps: Critical missing capabilities requiring investment	14
	C1-4	Cross-Border Technology Access: All-island and UK-wide technology sharing	15
	C1-5	Strategic Technology Priorities: Stakeholder-identified priority investments	23
C2 – Research Infrastructure	C2-1	National Research Centres: Major research centre models and investments	25
	C2-2	NI Regional Facilities: Existing and planned infrastructure	8
	C2-3	Infrastructure Gaps: Missing capabilities limiting competitiveness	12
	C2-4	Shared Facilities Model: Priorities for collaborative infrastructure	8
	C2-5	Systemic Infrastructure Challenges: Barriers to infrastructure development	18
C3 – Skills & Education	C3-1	Formal Training Programmes: Established education and training infrastructure	17
	C3-2	Critical Skills Gaps: Priority shortage areas requiring intervention	16
	C3-3	Strategic Skills Priorities: Stakeholder-identified priority competencies	12
	C3-4	Workforce Development Challenges: Structural barriers to talent pipeline	22
	C3-5	Public Engagement and Awareness: Building understanding and acceptance	8
C4 – Funding & Investment	C4-1	Grant Programmes and Public Funding: Established funding mechanisms	16
	C4-2	Strategic National Investments: Large-scale government programmes	14
	C4-3	Valley of Death Challenges: TRL 4–6 funding gaps and commercialisation barriers	11
	C4-4	Cross-Border Funding Opportunities: All-island and European funding access	20
	C4-5	Strategic Funding Priorities: Stakeholder-identified investment needs	15
	C4-6	Private Investment Landscape: Venture capital and private sector dynamics	17

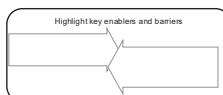
Sub-layer	Code	Cluster	Statements
C5 - Support Ecosystem	C5-1	European Support Infrastructure: EU-level support mechanisms and networks	27
	C5-2	US Support Programmes: American funding and support models	5
	C5-3	UK Regulatory Innovation: Regulatory frameworks supporting engineering biology	13
	C5-4	Regional Support Entities: NI-specific support infrastructure	20
	C5-5	Ecosystem Development Needs: Priorities for ecosystem strengthening	17
C6 - Enabling Collaborations	C6-1	International Collaboration Frameworks: Global governance and partnerships	15
	C6-2	All-Island Collaboration Models: North-South partnership opportunities	16
	C6-3	Coordination Gaps and Barriers: Structural challenges to collaboration	27
	C6-4	Strategic Collaboration Priorities: Stakeholder-identified partnership opportunities	10

Annex III: Topic Roadmaps Summaries

Initiative: Food Security and Resilience		Team:	Sharon, Adam, Linda
Pitch of this Value Proposition	Ensuring accessibility to safe & nutritious food, produced whilst delivering environmental & economic stability, using engineering biology.		
Strategic context including key drivers	Human & Planetary Health. Policy.		
Justification for activity	A resilient food sector which delivers affordable & nutritious food in a climate-smart manner underpinned by engineering biology.		
Main gaps and Risks	Expertise in NI in Eng Bio needs to be identified → allowing mapping & cluster-building. Risk of skill gap & NI falling behind globally in Eng Biol. TRL 3-4 — a lot of innovation at TRL 1-3 and 6 and above — but gaps in pipeline.		
Key outcomes and milestones (with dates) and parties to involve	<ul style="list-style-type: none"> - Map expertise (short-term) - Fund network of experts (short-term) - Identify skill gaps → towards larger cluster (medium term) 	<ul style="list-style-type: none"> * Fund engineering biology solutions at TRL 3-4 (short to medium term) * Larger strategy in place or UK-centred cluster funding (medium to long-term) 	Outcome — Enhanced ability to deliver eng bio-based innovation for the food sector.
Further research and projects required	Funding to Birmingham NI Diamond Triple-Helix Cluster — Eng Bio is key strand embedded within.		
Role of DfE and other ecosystem members	PhDs → point to Eng Bio as priority area (include DfE CAST). & Apprenticeships. DAERA/DfE collaboration to enhance NI capacity & capability across food sector i.e. pre- & post-farm gate eng bio innovations. Enable cluster-building → mapping via network → then enable gap-filling and larger cluster development.		
Monetary and non-monetary inputs, outputs and sharing	Invest in people & infrastructure → especially to scale-up innovations. Linked to above. Nurture NI Diamond into maturity → Eng Bio core strand within.		
Immediate actions to develop capabilities and overcome barriers	Map expertise & create network. Clearly define specific gaps & AU.		



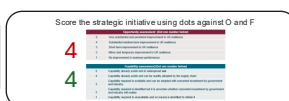
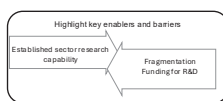
Initiative: Large Scale Capabilities (Catapult etc.)		Team:	Peter, Chris, Roisin, Derek, Simon
Pitch of this Value Proposition	Access to large scale EB capabilities (buy-in from Catapult, etc.).		
Strategic context including key drivers	Gap in essential industry need. (5.1)		
Justification for activity	Known existing customer pull for these capabilities in EB. Enable EB companies to win business that currently can't be won. Provide infrastructure to foster & scale SMEs.		
Main gaps and Risks	Lack of capacity as per strategic context. Failure to capture all Ireland & UK existing capacity. Need synergy.		
Key outcomes and milestones (with dates) and parties to involve	Thriving ecosystem of EB firms and SMEs with easy access to scale up capability & infrastructure driving economic growth.		
Further research and projects required	Understand current NI, Rol, UK landscape & NI USPs. Develop a business case for NI capability that meets Almac needs, university spinout/scale-up & FDI opportunities.		
Role of DfE and other ecosystem members	EB: Explore shared island & UK joint opportunities. DfE to derisk Cost modelling for developing ecosystem. Utilising pre-existing successful model (FMI).		
Monetary and non-monetary inputs, outputs and sharing	LIPF. UKRI/IUK. Almac buy-in / anchor tenant.		
Immediate actions to develop capabilities and overcome barriers	- As above in Research & Projects. - High level actionable strategy to develop EB.		



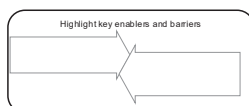
Initiative: Circular Bioeconomy		Team:	Emma, Bronagh, Phil, Patrick
Pitch of this Value Proposition	Renewable, traceable, circular bioeconomy that utilised biomaterials and waste (inc. agri + fisheries waste etc.) to create sustainable products and fuels, keeping products at a high value loops, eliminates waste, creates new economic value chains, enhances and enables natural environment		
Strategic context including key drivers	Lough Neagh provides an environmental challenge, coupled with the need to build more resilient supply chains to respond to geopolitical events that are impacting global supply chains		
Justification for activity	A3.2, A2.3, A1.3, + A5.5		
Main gaps and Risks	Nascent technology. Lack of connections across sectors. Capital for large scale deployment		
Key outcomes and milestones (with dates) and parties to involve	Bioremediation team in Lough Neagh to harvest algae to create biopolymers Coordinated circular bioeconomy cluster	Export this remediation tool and module.	Infrastructure in place to utilise biological and agri waste to enable large scale production and use of bioderived fuels
Further research and projects required	Feasibility for a modular biorefinery for algae activity above Mapping of key stakeholders and current state of play, plus a roadmap for circular bioeconomy		
Role of DfE and other ecosystem members	DfE: Create policy that enables a circular bioeconomy Fund mapping of stakeholders and roadmap for circular bioeconomy (AMIC could do this)		
Monetary and non-monetary inputs, outputs and sharing	UU, QUB & AMIC to deliver applied research and accelerate prototype and production/deployment and lean integration Industry to share waste data, participate in test beds and move to deployment		
Immediate actions to develop capabilities and overcome barriers	Track and map biological materials through sectors and system, identify opportunities. Off take model.		
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Initiative: Agri-tech sector disconnect requires better innovation policy alignment		Team:	Eoin, Katie, Elaine
Pitch of this Value Proposition	Commercially & environmentally sustainable agri-tech sector in AI.		
Strategic context including key drivers	Untapped potential for Eng Bio development in N.I. agri-tech.		
Justification for activity	Long term attractive but significant short/medium barriers		
Main gaps and Risks	Access to data & barriers incl. disclosure nature of NI farming community.		
Key outcomes and milestones (with dates) and parties to involve	Early engagement with DAERA & AFBI. — Access to data (go / no go).		
Further research and projects required	Organisation & accessibility of data.		
Role of DfE and other ecosystem members	DAERA is clear lead. Potential support from Artificial Intelligence Collaboration Centre & Digital Catapult & UK Agri-Tech Centre.		
Monetary and non-monetary inputs, outputs and sharing	Exposure of the quantum required — but likely to be significant.		
Immediate actions to develop capabilities and overcome barriers	Make relevant data available in (secure) accessible format.		
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Initiative: Diagnostics and Biosensors		Team:	Kathleen, Paul, Sam T., Steve
Pitch of this Value Proposition	Capacity to address grand challenges (health/agri/biotech) and emerging market opportunities.		
Strategic context including key drivers	Aligns with DFE/INI strategic sector. Aligns with NHS Reset Plan. Aligns with NI City Growth Deals.		
Justification for activity	Highly skilled workforce in diagnostics & biosensors. Thriving diagnostics sector. Internationally recognised academic research excellence in field. Nano Tech & Photonics at AMIC (£30m investment). UU, QUB, AFBI Trusts. NIBEC UU also.		
Main gaps and Risks	Don't have full pipeline. Connectivity of sector could be enhanced. Gaps in grant & VC funding. Gaps in biomolecular discovery / synthetic biology / some areas of nano engineering skills. Lack of connections with large bio tech corps. SWOT to be done.		
Key outcomes and milestones (with dates) and parties to involve	Diagnostics Forum (HIRANI?) Training schools	Accelerator programme (bespoke) Capability mapping	Skills development Encompass research capability maximised/data mining Sector sustainability
Further research and projects required	How biosensors can translate across sectors. Platform funding rather than application funding. Business case for investment in sector outlining vision. Build a biomarker database for disease. MATRIX — Capability mapping. Biosensor database.		
Role of DfE and other ecosystem members	HIRANI to lead diagnostics forum. QUB/UU/AFBI to lead training schools outreach (QUB/UU/AFBI). DFE form connections? Invest?		
Monetary and non-monetary inputs, outputs and sharing	Monetary — Investment (R&D/Infrastructure). Non-monetary — Steering group.		
Immediate actions to develop capabilities and overcome barriers	Discussion forum — Identify stakeholders.		



Initiative: 'One Health' across sectors		Team:	Rob, Aliyu, Eloise, Sam S., Tim, Ahmad
Pitch of this Value Proposition	How bioengineering can be employed across 'One Health' in NI to impact global health.		
Strategic context including key drivers	Climate change. AMR. Zoonotic infections. Fragile ecosystems. Changing health needs. EU Policy.		
Justification for activity	To determine if bioengineering provides us with the tools to address One Health challenges.		
Main gaps and Risks	Skills & retention. Isolated sectors. Silos (lack of communication). Lack of ringfenced funding. Data management and sharing. Public perception of bioengineering.		
Key outcomes and milestones (with dates) and parties to involve	1. Cross sector steering group 2. Dedicated resource — funding and physical space 3. New tools applied across sectors	1. 2026 – End 2. End 2027 3. Marketed product by 2030 onwards	1. Gov, Unis & Inst, Ind, HSC 2. 3. Uni & Industry
Further research and projects required	Platform development for tools for diagnostics, therapeutics, monitoring, vaccines.		
Role of DfE and other ecosystem members	Industry: Representative bodies e.g. Dairy Council — Policy drivers. Charitable sector — Funding focus. Gov. Depts: DFE, DAERA, DoH — Consistent and complementary policy alignment & funding. HE & R+D Institutes: Buy in in terms of strategy. Technology development aligned to One Health needs. Skills development.		
Monetary and non-monetary inputs, outputs and sharing	Ringfenced specific funding targeted at bioengineering to address One Health challenges in NI. Data from Gov and industry and citizens. Skills — specialists and generalists.		
Immediate actions to develop capabilities and overcome barriers	- Map and build upon existing initiatives. - Gap analysis. - Set up One Health forum.		



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Science Industry Panel**

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