Future Proofing the Irish Agri-Food Sector Through Robust Research

A report for

**NUFFIELD IRELAND
Farming Scholarships**

by Karina Pierce

2019 Nuffield Scholar

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1. Executive Summary

Research seeks to address agri-food challenges and is critically important as a driver of innovation and competitiveness of our agri-food industry. The industry faces many challenges, such as meeting our environmental commitments, climate change, growing anti-agriculture sentiment and addressing consumer concerns around animal welfare. Many of these challenges are not specific to Ireland, but are indeed global challenges, and therefore Ireland can learn from the experience of others.
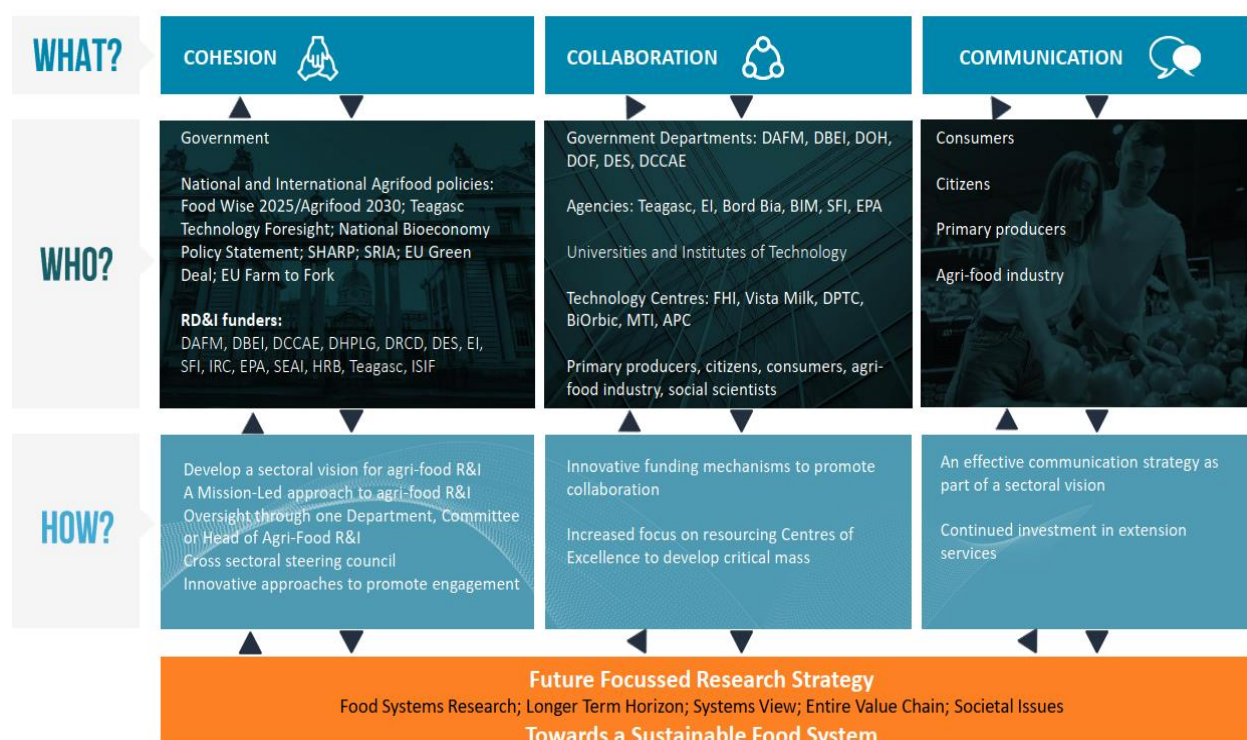
The overall aim of this study was to evaluate if the future needs of Irelands agri-food sector are being addressed through current research. The objectives were to: review the research landscape in Ireland including the main funding agencies and research performing organisations, investigate current and future focussed research priorities in Ireland and other major agri-food producing countries, with a focus on pasture-based production systems and finally to identify key concepts and actions required for the development of a future focussed research and innovation agenda. The objectives were met through visits and meetings with a broad range of researchers, farmers, publicly funded organisations, Government officials, entrepreneurs and businesses over the course of my Nuffield travels to 11 countries including, America, China, New Zealand, Australia, France and Belgium.

The main findings of the study showed that the RD&I system has a key role to play in providing solutions to transform the food system into more sustainable, resilient, responsible, diverse, competitive and inclusive pathways. However, the Irish agri-food sector, when benchmarked against its global competitors, underperforms in terms of RD&I expenditure. To be transformative, there needs to be a move from component type research to a more systems approach that incorporates all elements of the food chain, from primary production through to the health and behaviour of consumers. Given the complexity of the issues facing the sector, a major focus on fostering a collaborative environment around key industry issues is critical as strong partnerships between industry, policy-makers and research providers will be required to ensure that science is translated into strong business, policy and management decisions.

There is a need for a national agri-food research and innovation policy to give direction to strategy and investment decision-making by funders, research and development providers, industry and Government departments. A 'mission led' approach could be beneficial to ensure that funded research is targeted to solving the grand challenges facing the industry. Greater oversight and coordination through a single Government Department or committee, or by appointing an Head of Agri-food RD&I could be beneficial in this regard.

From this study it is evident that Cohesion, Collaboration and Communication are key to the development of a future focussed research agenda that will form a critical component of a sustainable agri-food system. The graphic below outlines the key concepts and actions required to facilitate this.

Figure 1: Cohesion, Collaboration and Communication. Key concepts and actions required in the development of a future focussed research and innovation agenda

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3. List of Abbreviations

APC	Alimentary Pharmabiotic Centre
BIM	Bord Iascaigh Mhara
CAAS	Chinese Academy of Agricultural Sciences
CSO	Central Statistics Office
CAP	Common Agricultural Policy
CFS	Committee on World Food Security
CSC	Contemporary Scholars Conference
DAFM	Department of Agriculture, Food and the Marine
DBEI	Department of Business, Enterprise and Innovation
DCCAE	Department of Communications, Climate Action and Environment
DES	Department of Education and Skills
DHPLG	Department of Housing, Planning and Local Government
DRCD	Department of Rural and Community Development
DPTC	Dairy Processing Technology Centre
EI	Enterprise Ireland
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation of the United Nations
FNS	Food and Nutrition Security
GFP	Global Focus Programme
GHGs	Greenhouse Gases
GNP	Gross National Product
HRB	Health Research Board
KTI	Knowledge Transfer Ireland
ICBF	Irish Cattle Breeding Federation
IP	Intellectual Property
IRC	Irish Research Council
ISIF	Ireland Strategic Investment Fund
MPI	Ministry for Primary Industries
MTI	Meat Technology Ireland
NDC	National Dairy Council
NFU	National Farmers Union
NGO's	Non-Governmental Organisations
NUE	Nitrogen Use Efficiency
PPI	Patient and Public Involvement
R&I	Research and Innovation
R&D	Research and Development
RD&I	Research, Development and Innovation
SEAI	Sustainable Energy Authority of Ireland
SFI	Science Foundation Ireland
TRL	Technology Readiness Level
UN	United Nations
UN SDG's	United Nations Sustainable Development Goals

4. Acknowledgements

Firstly, I would like to thank Nuffield Ireland and FBD Trust for the fantastic opportunity afforded to me. To John Tyrell, Geoff Dooley and Karen Brosnan, I am extremely grateful for all your support and encouragement along the way. A special note of thanks to my Mentor, Mary Webb, who has been a rock of support from the beginning, not allowing me to wallow in any self-doubt. Sincere thanks to all my colleagues in the School of Agriculture and Food Science in UCD for your support and for covering for me while I travelled - and making it seem like it was no bother at all. To all who read my report and advised me in so many ways at various stages along this journey, especially Profs Dermot Ruane and Frank Roche.

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To the many people who hosted me along the way and who were so generous with their time - you made the whole experience so interesting and enjoyable. Thank you all.

To my Japan GFP group, Alison Holmes, Al Corr, Tash Shields, Hamish Marr, Rose Danagher, Allan Cooper, Renee Anderson Willem Vonken, Richard Leask and Christoph Weder. Thank you for your friendship and the most amazing memories. You will always be 'Forever Young'.

To Denis, Niamh and Conor who have been fully behind me during this whole adventure and my family in Wicklow, Laois and the USA who pitched in to support us, particularly while I travelled. Thank you all.

As I reflect over the last two years, particularly in light of Covid19 and the resultant restrictions on travel, my Nuffield scholarship has been one of the best experiences of my life in terms of the people I got to meet, the places I got to see, the network of contacts I developed and the many unintentional friends I made along the way. To everyone who made it this way, thank you.

5. Personal Introduction

Agriculture has been a key part of my life since I was a child. Both my parents were raised on farms and we moved to the farm I grew up on when I was just two years old. I often think how different my life would have been if this major event hadn't happened. The farm at that time was a small sheep and suckler farm outside of Roundwood in Co. Wicklow. My brother farms there now, but only farms sheep on a part-time basis. We have beautiful views, but it is a challenging place to farm, especially over the winter and spring months. I have however, the very best of memories growing up on the farm and without doubt, it shaped me, and my interest in agriculture from an early age.

I studied Agricultural Science at UCD and following this completed a PhD in swine nutrition, focussing on gut health and replacing sub-therapeutic antibiotics in pig diets. My first job was as an Animal Nutritionist with Brett Brothers in Co. Kilkenny, where I made great contacts in the industry and learned a huge amount during the two years I was there. I went back to UCD in 2006, first as a Post-Doctoral Researcher and then as a Lecturer and Researcher in Dairy Production before moving to Enterprise Ireland as a Senior Development Advisor in the Food Division (dairy and nutrition) in May of this year.

I am married to Denis and we have two children, Niamh and Conor. Life is certainly busy, but with great support from friends, work colleagues and family, I was able to take on the challenge of a Nuffield Scholarship, and it has been one of the best experiences of my life.

Figure 2: Japan GFP group in West Virginia, USA.

6. Rationale

The agri-food sector is Ireland's largest indigenous industry and in 2019, achieved revenues of €26bn and exports of approximately €13bn, representing a 67% increase over a 10-year period (Bord Bia, 2019). However, substantial challenges lie ahead in the coming decades. Agriculture globally must produce more food for a growing, increasingly affluent population, while competing for access for increasingly scarce natural resources, preserving biodiversity and water quality, mitigating the effects of climate change, adapting to new plant and animal disease threats and addressing consumer concerns around issues such as animal welfare.

Given the pasture-based nature of Irish agri-food production, Ireland is well placed to meet the challenges of feeding a growing global population. However, consumers of Irish food are asking more about the sustainability of our production systems and therefore, the rapidly increasing demand for food must be met in ways that are sustainable (Curtin and Arnold, 2016). Given the scale of the challenges faced by the industry, a collaborative approach by all stakeholders involved will be essential if solutions are to be found.

Research seeks to address these agri-food challenges and is critically important as a driver of innovation and competitiveness of the sector (DBEI, 2018). From a business perspective, RD&I proactive companies have been shown to generate higher exports and sales (Teagasc, 2019). As an exporter, Ireland must be conscious of what our customers are focussing on, and what areas of research our competitors are investing in, in the short, medium and long term. Many of the challenges are not specific to Ireland, but are indeed global challenges, as expressed through the UN Sustainable Development Goals (SDGs). Ireland can therefore learn from the experience of others. By having this information, we can make more informed decisions about the best direction of our own RD&I investment.

7. My Study Tour

'You are part of an organisation that means something, and people are aware of it. Use that'. Undersecretary Bill Northey on Nuffield.

Below is a summary of my travel to 11 countries over 12 weeks during 2019 and early 2020.

March 2019: Contemporary Scholars Conference, Ames, Iowa, USA

Nuffield International hosts an annual Contemporary Scholars Conference (CSC), which is a week-long program for newly selected scholars, held in member countries and rotated between the Northern and Southern Hemispheres. The 2019 conference was held in Ames, Iowa, USA with the 67 new (2019) Scholars. The CSC offers an important opportunity for new Scholars to meet and network with their peers and make contacts for their study topic and future travels.

June-July 2019: Global Focus Program. Singapore, Indonesia, Japan, France, Canada, USA

The Irish Scholars participate in a six-week 'Global Focus Program' (GFP) world tour to develop a greater understanding of local and international agricultural best practice and meet with progressive businesses, organisations and government. The first stop on my GFP was to Singapore and the following 6 weeks saw me in Japan, Indonesia, France, Canada and the USA. The GFP was an amazing experience and one that challenged me every day. The challenges presented were sometimes less about the technical information we received and tried to absorb each day, and more about the personal challenges of being away from home, being part of a group of 10 individuals who didn't know each other before we set off, getting to know one another as we moved around the world and learning new things about myself on a daily basis. As I reflect now, the GFP is one of the most rewarding and memorable events of my life.

October 2019: United Nations Committee on Food Security, Rome, Italy

'The faith of the world is in the hands of the people who show up', Wayne Dredge, Nuffield Scholar.

The United Nations (UN) Food and Agriculture Organisation (FAO) Committee on Food Security (CFS) meeting takes place in October in Rome. The CFS develops and endorses policy recommendations and guidance on a wide range of food security and nutrition topics. It is an international and intergovernmental platform for stakeholders to work together towards food security and nutrition for all. As a result, it is a forum that attracts a very broad range of stakeholders, from Diplomats and Ambassadors, with significant representation from the private sector and civil society also. There are important decisions made during this annual event that influence policy, that will eventually impact all of us working in the agri-food sector.

October-November 2019: China (Beijing), New Zealand and Australia

The Chinese market is one of growing importance for Irish agri-food exports. The Chinese Academy of Agricultural Science (CAAS), based in Beijing, has 42 Institutes and has responsibility for carrying out both basic and applied research, as well as research into new technologies impacting agriculture.

New Zealand has long been a focal point for Irish dairy because of its grass-based nature. New Zealand has in recent years, been struggling with growing environmental issues and anti-dairy sentiment and with similar concerns in Ireland, we can learn from the focus and direction of their research to tackle these issues.

Following years of decline, there is renewed focus on grass-based dairy production within Australia. However, the dairy industry remains in difficulty and the focus of future research programmes to address the key issues facing the industry is of interest from an Irish perspective.

February 2020: Brussels

Brussels, as the home of the European Commission, provides not only funding, but also direction to agri-food related research programmes in Ireland. The EU Green Deal and The Farm to Fork proposals will strongly influence RD&I programmes here over the coming decade.

Figure 3: Nuffield Scholars attending meetings in Washington DC (3a), the UN FAO CFS Meeting in Rome (3b), a strawberry farm in Nova Scotia, Canada (3c), dairy farming in Japan (3d), visiting the Chinese Academy of Agricultural Sciences in Beijing (3e) and 'Greenfields' dairy farm in Surabaya, Indonesia (3f)

3a

3b

3c

3d

3e

3f

8. Introduction

The agri-food sector is Ireland's largest indigenous industry. According to recent data from The Department of Agriculture, Food and the Marine (DAFM, 2018), employment in the agri-food sector accounts for approximately 173,000 jobs or 7.7% of total employment in Ireland. The sector represents 7.7% of modified Gross National Income and 10% of total exports and in 2019, the sector achieved revenues of €26bn. The estimated value of food, drink and horticulture exports in 2019 was €13bn (Bord Bia, 2019), representing a 67% increase over a 10-year period. The value of Irish dairy exports stood at €4.4bn, accounting for 34% of Irish food exports, while the same figures for meat and livestock exports were €3.9bn and 30% respectively, highlighting the importance of ruminant-based agriculture to the Irish economy (Bord Bia, 2019).

World population is on the rise and is projected to reach 8.6 billion in 2030 and 9.8 billion by 2050. Of the projected additional 2.4 billion people to be added to the global population between 2015 and 2050, 1.3 billion will be from Africa and 0.9 billion from Asia (UN, 2017). The growth in population and rising incomes are important drivers of world food demand (Mohammad and Karim, 2019). Income growth increases overall consumption, leads consumption towards high-value products and also to changes in consumer preferences (European Commission, 2019a). These changes move in very different patterns and paces in different parts of the world and result from societal habits, health concerns, and emerging drivers, such as environmental or climate change issues. Income growth in emerging economies leads to increasing consumption of products of higher value such as meats and dairy products, while rising societal and environmental concerns in developed economies leads to lower red meat consumption (European Commission, 2019b).

Given the pasture-based nature of Irish agri-food production, Ireland is well placed to meet the challenges of feeding a growing global population (Teagasc, 2016). Indeed, there are ambitious growth targets for the sector, with Food Wise 2025 (DAFM, 2015) targeting further growth in exports to €19bn by 2025. However, the rapidly increasing demand for food from a growing and more affluent global population must be met in ways that are sustainable in

the face of climate change, as well as other environmental challenges such as water stress and biodiversity loss (Curtin and Arnold, 2016).

Table 1: Population of the world by region

Major region	Population (millions)			
	2015	2030	2050	2100
World	7 349	8 501	9 725	11 213
Africa	1 186	1 679	2 478	4 387
Asia	4 393	4 923	5 267	4 889
Europe	738	734	707	646
Latin America and the Caribbean	634	721	784	721
Northern America	358	396	433	500
Oceania	39	47	57	71

Source: Mohammad and Karim (2019)

Research seeks to address national agri-food challenges and is critically important as a driver of innovation and competitiveness of our agri-food industry (DBEI, 2018). Research is recognised as the path to innovation and commercialisation and RD&I proactive companies have been shown to generate higher exports and sales (Teagasc, 2019). High quality research is critically important for a country as it provides the means for the type of innovation essential to an economy in order to sustain and expand economic growth and to maintain competitiveness (EPRS, 2019). As an exporter, Ireland must be conscious of what our customers are focussing on, and what areas of research our competitors are investing in, in the short, medium and long term. As highlighted above, the industry faces many challenges, such as meeting our environmental commitments, climate change, growing anti-agriculture sentiment, reducing farm incomes and consumer concerns around issues such as animal welfare. Many of these challenges are not specific to Ireland, but are indeed global challenges, and therefore Ireland can learn from the experience of others. By having this information, we can make more informed decisions about the best direction of our own research investment. Indeed, the investment from the Irish Government in agri-food RD&I is significant, with approximately €157 million of public money committed in 2018 (HLIC, 2019). This funding is distributed through numerous state and semi state agencies such as the DAFM, Teagasc,

Science Foundation Ireland (SFI), Enterprise Ireland (EI) and the Environmental Protection Agency (EPA). As in many other countries, there is an increasing requirement for private industry to fund research (DAFM, 2015) and currently, there is an estimated €124 million from private industry invested in RD&I on an annual basis (HLIC, 2019). Given the scale of the challenges facing the sector, a collaborative approach by all stakeholders involved will be essential if sustainable solutions are to be found. While it is positive to see strong public funding for RD&I in the agri-food sector, increased funding also raises questions of accountability, i.e. how to prioritise expenditure and measure and evaluate the outcomes of research projects.

9. Aims and Objectives

9.1 Aim

The overall aim of the study was to evaluate if the future needs of Irelands agri-food industry are being addressed through current research.

9.2 Objectives

The **objectives** of this study were to:

1) review the research landscape in Ireland including the main funding agencies and research performing organisations
2) investigate current and future focussed research priorities in Ireland and other major agri-food producing countries, with a focus on pasture-based production systems
3) identify key concepts and actions required for the development of a future focussed research and innovation agenda

10. Research Approach and Methodology

The countries visited as part of this research project were The United States, Singapore, Japan, Indonesia, France, Canada, China, Australia, New Zealand, Italy and Belgium. Visits and meetings with a broad range of researchers, farmers, government officials, entrepreneurs and businesses were held over the course of the study (see Table 2). Each visit involved a semi-structured interview with notes written up after each meeting and formulated into this report where relevant. Secondary sources of information involved an extensive review of the literature, including policy documents and scientific publications to assess current research and future strategies in Ireland and internationally. Learnings to date have been disseminated through articles in the Irish Farmers Journal as well as various presentations and discussions with Irish Stakeholders.

Table 2: Study tour itinerary and contacts (Source: Author)

Date	Country	Contact
October 2018	Netherlands (met in Italy)	Prof Martin Scholten. Member of the Board of Directors of Wageningen University & Research
January 2019	Northern Ireland	Prof Nigel Scollan, Director Institute Global Food Security, Queens University Belfast
	Ireland	Prof Jimmy Burke, Director of Research, Origin Enterprises
March 2019	United States	Prof. Surya Mallapragada, Associate VP for Research, Iowa State University
		Prof. Mathew O'Neal, Programme Chair, Sustainable Agriculture, Iowa State University
		Prof. Joe Colletti, Interim Dean, Natural Resource Ecology and Management, Iowa State University
April 2019	Ireland	Prof Frank O'Mara, Director of Research, Teagasc
		Zoe Kavanagh, Chief Executive, National Dairy Council
August 2019	Ireland	Dr Pam Byrne, CEO Food Safety Authority of Ireland
		Prof Dermot Ruane, UCD
September 2019	Ireland	Prof Frank Roche, Professor Emeritus, UCD and Member of the Food Wise 2025 High Level Innovation Committee
	Northern Ireland	Prof Nigel Scollan, Director Institute Global Food Security, Queens University Belfast
October 2019	Rome, Italy	Ambassador Colm O'Floinn and Deputy Permanent Resident, Paul Kiernan
		Caroline Emund, Director General, International Dairy Federation
	Ireland	Prof Frank Roche, Professor Emeritus, UCD and Member of the Food Wise 2015 High Level Innovation Committee
	Beijing, China	Prof. Dengpan Bu, Director, Institute Animal Science, Chinese Academy of Agricultural Sciences

November 2019	New Zealand	David Williams, National Milk Supply Manager, Synlait
		Prof Alan Renwick. Professor of Agricultural Economics, Lincoln University
		Prof Hugh Bigsby. Dean. Faculty of Agribusiness and Commerce, Lincoln University
		Dr Val Snow. Agro-ecosystem modeller, Senior Scientist, AgResearch
		Dr Callum Eastwood. Scientist, DairyNZ
		Ray McLeod, General Manager, Landward Management Ltd.
		Carmen and Chris Ryan. Dairy Farmers
		Dr Naomi Parker (Manager Science Policy) and Dr Gerald (Policy and Trade). Ministry for Primary Industries
		Prof Gary Evans, Chief Science Advisor. Ministry for Business, Innovation and Employment (MBIE)
		Dr Mark Aspin. Scientist and General Manager Pastoral Greenhouse Gas Research Ltd. Beef and Lamb New Zealand
		Prof Hamish Gow, Professor of Agribusiness, Massey University
		Duncan Coull, Hamilton. Dairy farmer and recently retired council member of Fonterra
		Bryan McKay and Sue Macky, Agricultural Consultants, Dairy Farm Systems Ltd. Hamilton
		John Hall. Director, AgFirst. Agricultural Consultants. Hamilton
		Dr Tim Mackle, CEO and Dr Bruce Thorrold, Head of Investment and Research Strategy. Dairy NZ. Hamilton
	Australia	Ruari McDonnell, Lead: Feedbase and Nutrition. Dairy Australia
		Brendan Cullen, Senior Lecturer, Grazing Systems and Prof Richard Eckard, Professor and Director of Primary Industries Climate Challenges Centre, University of Melbourne
		Oonagh and Harper Kilpatrick. Dairy farmers. Southern Cross, Victoria
		Kevin Argyle, Director, Major Innovation Projects. Farm Profit and Capability. Dairy Australia, Southbank Victoria
		Professor Frank Dunshea, Chair of Agriculture in the Faculty of Veterinary and Agricultural Science, University of Melbourne
	Ireland	Michael Berkery, Chair FBD Trust
December 2019	Ireland	Prof Frank Roche, Professor Emeritus, UCD and Member of the Food Wise 2015 High Level Innovation Committee
		Conor Mulvihill, Director, Dairy Industry Ireland
January 2020	Ireland	Triona McCormack, Director of Research, UCD
		Richard Howell, Snr Inspector, Research, Food and Codex Division. Department of Agriculture, Food and the Marine
February 2020	Ireland	Alison Campbell, Director, Knowledge Transfer Ireland
		Dr Pam Byrne, CEO, Food Safety Authority of Ireland
	Brussels, Belgium	Breffni Carpenter, Councillor (Agriculture), Department of Foreign Affairs and Trade
		Alison Graham, Executive, European Affairs, Irish Cooperative Society
		David Lambe, Network Manager, European Network for Rural Development

		Mella Frewen, Director General, Food&Drink Europe and Member of the Food Wise 2015 High Level Innovation Committee
		Dr Karen Fabbi, Deputy Head of Unit, European Commission, DG Research and Innovation, Bioeconomy and Food Systems, Healthy Planet Directorate
March 2020	Ireland	Cathal McCormack, Neil Keane and Richard Murphy, Alltech Ireland
		Patrick Barrett, Research & Codex Division, Department of Agriculture, Food and the Marine
		Alexa Toomey, Department Manager. Dairy Drinks & Food Foreign Direct Investment, Enterprise Ireland
		Prof Jimmy Burke, Director of Research, Origin Enterprises
April 2020	Ireland	Tom Arnold, Chair, Agrifood 2030 strategy committee (via phone)
		Aidan Connolly, CEO Cainthus and formerly Head of Innovation at Alltech (via Zoom)
		Richard Kennedy, CEO Devenish Nutrition and EY Winner 2019 (via Zoom)
May 2020	Ireland	Dale Crammond, Agricultural Inspector, Department of Agriculture, Food and the Marine (via Zoom)
June 2020	Ireland	Ellen Ni Cleirigh, Snr Commercialisation Specialist, Enterprise Ireland (via Zoom)
		Dr Miriam Ryan, Head of Regulatory Affairs, Dairy Industry Ireland (via Zoom)
		Dr Nessa Noronha, Director of Food for Health Ireland (via Zoom)
		Dr Kirsty Dougal, Acting Head of Strategy, Agriculture and Biotechnology and Biological Sciences Research Council (BBSRC), UKRI

11. The Irish Agri-Food Research Landscape

11.1 Overview

There is a very substantial agri-food RD&I programme ongoing in Ireland when activities across the Research Performing Organisations (RPO's) such as Teagasc, the universities and Institutes of Technology are considered. The emergence of technology centres has also increased RD&I activity and collaboration between the RPO's and private industry. There is considerable investment by the State in RD&I in the agri-food sector, estimated at €157 million in 2018 (HLIC, 2019). This figure actually underestimates the support for RD&I, as it does not reflect other funding through state agencies such as Bord Iascaigh Mhara (BIM), EPA, the Climate Action Fund, Regional Enterprise Development Fund etc. that contribute significantly to RD&I activity. Innovation 2020, a five-year strategy on R&D, science and technology had a target to increase Ireland's R&D intensity to 2.5% of GNP by 2020. The continued support for RD&I from successive Governments in recent times has resulted in there now being significant infrastructure, capacity and capability in the publicly supported RPOs.

As a result of the economic crash, business investment in RD&I grew by 31%, while public spending fell 22% between 2008 and 2013. Despite this increase in industry investment, funding from private industry in RD&I remains quite low in the Irish agri-food sector and the sector under performs when benchmarked against its global competitors. In the dairy sector, the typical rate of <0.5% of turnover is well below the best-in-class companies such as Friesland Campina or Arla where expenditure levels ranging between 2.0% - 2.5% are the norm. Indeed, Food Harvest (DAFF, 2010) and Food Wise 2025 (DAFM, 2015) recommended a significant increase in industry investment in RD&I in order to realise the potential that exists across the sector and within our research and commercialisation network. Survey data from EI in 2018 shows that the €123.6 million spend by the Food and Beverage processing sector equated to 0.63% of turnover or 91% of the Public Sector spend. The same survey shows that the majority of food and beverage companies spent less than €100,000 on R&D in 2018. Despite this, a UCD study by Renwick et al. (2014) concluded that Ireland had the 5th most

innovate agri-food sector in the EU, behind Denmark, Finland, the Netherland and Germany. The benefits from investment in RD&I were highlighted recently by EI, with companies investing in research and innovation generating 67% more in global sales than those that don't (Enterprise Ireland, 2020).

11.2 Is All Research the Same?

In a mature and functioning RD&I system, the research focus should spread across from basic (fundamental) to applied research and also across the whole Technology Readiness Level (TRLs) spectrum, albeit with greater focus on TRLs in the mid-range rather than at either extreme. The TRL scale was originally defined by NASA in the 1990's as a means for measuring or indicating the maturity of a given technology. The TRL spans over nine levels (see Figure 3) with higher TRLs reflecting greater maturity of the technology.

Figure 4: Technology Readiness Level (TRL) scale (OAST, 1991)
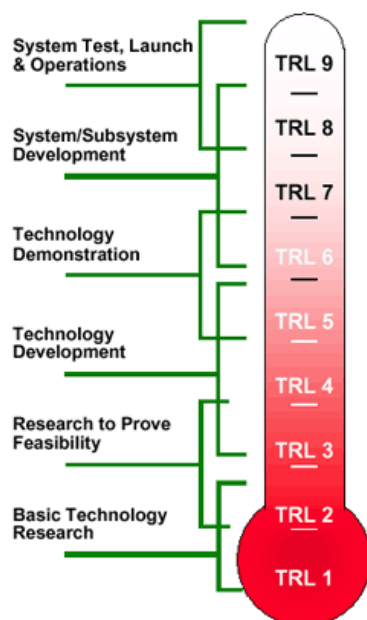
Basic research is curiosity driven. It is motivated by a desire to expand knowledge and involves the acquisition of knowledge for knowledge's sake. It is intended to answer why, what or how questions and increase understanding of fundamental principles. Basic research does not have immediate commercial objectives and although it certainly could, it may not necessarily

result in an invention or a solution to a practical problem. Applied research on the other hand is designed to answer specific questions aimed at solving practical problems. New knowledge acquired from applied research has specific commercial objectives in the form of products, procedures or services (Hale, 2018). Teagasc, as a major actor in the agri-food R&I system, have a split of approximately 70:20:10 applied research to basic to experimental development respectively, resulting in the majority of research projects falling within TRL levels 5 and 6 (Kelly, 2018).

The economic downturn in Ireland increased the focus on investment in applied/higher TRL research with a presumed more immediate impact for the economy. Indeed in 2015, basic research as a percentage of GDP in Ireland was 0.20, lower than Denmark (0.58), the Netherlands (0.54), Italy (0.33) and the UK (0.28) (Purcell, 2020). At times of improved national finances, there is opportunity to refocus somewhat on basic research with a longer term, more strategic focus to ensure we are future-proofing the sector against some of the significant challenges the industry is facing (Howell, 2020 per comms).

11.3 Major Funders of Irish Agri-Food Research

This section focuses on public funds invested in RD&I. However, there is also an estimated €124 million from private industry invested in RD&I on an annual basis (HLIC, 2019), equating to approximately 91% of the Public Sector spend.

Department of Agriculture, Food and the Marine

The DAFM supports RD&I in the agri-food sector through 'public good' competitive research funding programmes (FIRM and Stimulus) and through the core grant-in-aid funding provided to agencies under its aegis, namely Teagasc and the Marine Institute, while other bodies, co-funded by DAFM such as the Irish Cattle Breeding Federation (ICBF), are also involved in RD&I activities. The DAFM also provides support for Irish involvement in the EU Horizon 2020 research funding programme.

Science Foundation Ireland

Science Foundation Ireland is Ireland's largest research funding body, funding orientated basic and applied research in the areas of science, technology, engineering and mathematics. Science Foundation Ireland is not a traditional funder of agri-food RD&I but has recently co-funded VistaMilk, a research centre for innovative precision pasture-based dairying, hosted by Teagasc. They have funded the Alimentary Pharmabiotic Centre (APC) Microbiome Ireland Centre in University College Cork since 2003.

Enterprise Ireland

Enterprise Ireland is the Government agency responsible for supporting Irish businesses in the manufacturing and internationally traded service sectors. They have a range of supports for higher TRL research and to assist companies in developing new and improved products, processes and services including their Innovation Partnership Programme, commercialisation funds and funding for technologies centres (e.g Food for Health Ireland, Dairy Processing Technology Centre, Meat Technology Ireland).

European Funding - Horizon 2020

Horizon 2020 had a budget of nearly €80 billion of funding available over the seven-year period from 2014 to 2020. A key theme for Horizon 2020 was 'Food & Healthy Diet' that included activities promoting informed consumer choices; delivery of strategic solutions for healthy and safe foods and diets for all; and creating opportunities for a sustainable and competitive agri-food industry, through innovation in food processing. Ireland has a national target of €1.25bn of funding under Horizon 2020. Horizon Europe, a seven-year programme (2021-2027) will succeed Horizon 2020 and raise spending in RD&I to €100 billion over that period.

Other Funders of Agri-Food Research:

Levy Funded Research

Levy funds are collected in the dairy, beef, tillage and pig sectors to primarily fund applied research targeted at farmers and industry with the aim of improving efficiencies and profitability. In dairy, the current contribution by milk producers amounts to 0.036c/litre or approximately €125 per dairy farmer. The overall contribution by Irish dairy farmers is over €1.8m.

The EPA, Health Research Board (HRB), Irish Research Council, Bord Bia, BIM and the private sector also fund research in the agri-food space with support for postgraduate scholarship programmes, infrastructure and research.

11.4 Ireland's Key Research Performing Organisations

Teagasc

Teagasc is the largest public RPO outside of the university system in Ireland. It is an independent government agency under the auspices of the DAFM, with a statutory role in the provision of research for the Irish agri-food sector. Teagasc receives approximately €70 million annually from the state for RD&I and ranks highly internationally for its RD&I activities.

Universities and Institutes of Technologies

Many of Ireland's 7 universities and 14 Institutes of Technology perform impressively well at international level in agri-food disciplines employing some of the most highly cited scientists in the world. University College Dublin (UCD) for example, is now placed 5th in Europe and 19th globally and is the only Irish university to make the global top 50 in the rankings for Agricultural sciences (U.S. News & World Report rankings, 2019).

Technology Centres

Ireland's Technology Centres have a significant impact on the research landscape nationally as they provide a framework that facilitates small companies and start-ups to collaborate with larger companies along with research teams in Teagasc and higher education institutes on research topics of mutual interest, identified primarily by industry. They also provide a path to commercialisation for Intellectual Property (IP) emerging from the public research system. Market-focused research and technology centres are a vital part of the system of public support for enhancing the competitiveness of enterprise through innovation and the commercialisation of research. The main Technology Centres of importance to the food industry include, Food for Health Ireland, the Dairy Processing Technology Centre, Meat Technology Ireland, Innovation for Ireland's Energy Efficiency (I2E2) and the Irish Centre for Manufacturing Research (all funded by EI) , Alimentary Pharmabiotic Centre (APC) and more recently, VistaMilk, both funded by SFI.

Other Research Performing Organisations

The Marine Institute, EPA and the Food Safety Authority of Ireland are also active in agri-food research.

12. Current and Future Research Priorities

'If you don't like change, you are going to like irrelevance even less' General Shinseki

12.1 Ireland

The Government's 2013 National Research Prioritisation Exercise identified 'Sustainable Food Production and Processing' and 'Food for Health' as two priority areas. Identifying priority areas acts to set the agenda for technologies, capabilities and IP emerging from Irish research institutions. The prioritisation of these topics in the National Research Prioritisation Exercise led to the 'Sustainable Healthy Agri-food Research Plan' (SHARP) strategic agenda in 2015. SHARP was developed by a cross-funder working group led by the DAFM under the Research Prioritisation Action Group (RPAG) and reflected input from a broad range of industry stakeholders including Government Departments, funding bodies, the research community and broader society. SHARP identified a number of research priority areas (Figure 5) that acted as a blueprint to guide the funding decisions of all relevant funders in the years since then. The SHARP strategy was built around three guiding principles – competitiveness, sustainability and citizen/consumer orientation and it was the first time that Irish research funding bodies, researchers across food, farming and health sectors came together to identify R&I opportunities.

Innovation 2020 (DBEI, 2015) is Ireland's five-year strategy on R&D, science and technology and sets out the roadmap for continuing progress towards the goal of making Ireland a global innovation leader.

Figure 5: Key research and thematic areas for Sustainable Food Production and Processing and Food for Health Priority areas (source: SHARP, 2015).

12.1.1 Future Focussed Research Priorities

As a significant exporter of dairy and beef products, consumers of Irish food are asking more about the sustainability of our production systems. Sustainability is embedded in our international food marketing (Origin Green) and will remain a key issue for Irish agriculture. Ireland has also signed up to challenging environmental/emissions reduction targets that will require significant practice change and greater adoption of new and existing technologies in order to achieve the targets.

Teagasc as a key player in the RD&I system in Ireland, plan to focus on the following areas as future priorities: genetics and genomics, sexed semen and IVF, grassland management, digitalisation of agriculture, animal health and welfare, antimicrobial and anthelmintic resistance, soil health (soil microbiome and regenerative agriculture), tillage crops for high value markets, reducing reliance on pesticides, circular bioeconomy (integrated dairy calf to beef; bio-transformation), gaseous emissions and alternative proteins. The majority of funding currently is short-term focussed and Prof Frank O'Mara, Director of Research with Teagasc emphasised the need for funding for longer term projects, with the potential to create new knowledge that could be transformative for the sector.

Discussions with other industry Stakeholders as part of this study highlighted that while there is excellent work ongoing and talented people involved in RD&I in Ireland, a number of challenges exist for the Irish agri-food research system.

- In order to be transformative, there needs to be a move from component type research to a more systems approach that incorporates all elements of the food chain, from primary production through to the health and behaviour of consumers. To achieve this, strong partnerships between industry, policy-makers and research providers will be required to ensure that science is translated into strong business, policy and management decisions.

- There needs to be a major focus on fostering a collaborative environment around key industry issues. While there is significant public investment in agri-food RD&I, there have been missed opportunities to align investments across the range of funds and funders in our science system.

- As national governments continue to reduce their contribution to RD&I funding and ask more of private industry, the implications for this in terms of perceived independence and acceptability of the research by the public/consumers needs due attention. In this regard, challenges exist with the growing use of new technologies, such as robotics, genetics, biotechnology and automation. These technologies will require engagement among science, industry and the public to consider social licence for their use and wider potential impacts on the environment.

12.2 European Union

Horizon Europe, the seven-year programme (2021-2027) to succeed Horizon 2020 programme will support the development of lower input, 'more sustainable' systems and has been informed by several policy documents including Food 2030, that advocates for transformation of food systems under four thematic areas: 1) nutrition for sustainable and healthy diets; 2) climate smart and environmentally sustainable food systems; 3) circularity and resource efficiency of food systems and 4) innovation and empowerment of communities. Horizon Europe will also be influenced strongly by the Farm to Fork policy document as part of the EU Green Deal proposals. Farm to Fork is advocating lower input agricultural systems with significant reductions in the levels of pesticides and fertilisers

proposed. This move to lower-carbon/lower-input systems will present challenges for the resilience and competitiveness of our agri-food sector.

Dr Karen Fabbri in DG Research stated clearly that the view within the European Commission is that future food production systems must be sustainable in terms of delivering a supply of safe, healthy food with low environmental impacts in terms of emissions and biodiversity and utilisation of natural resources. This will require a hugely enhanced level of innovation and involve major improvements in efficiency and waste reduction as well as access to new types of technology.

In view of the global Food and Nutrition Security (FNS) challenges and the goals set by the UN in the SDGs, there is an urgent need to improve the effectiveness of, and increase investments in, RD&I for food systems. The importance of sustainability is being recognized throughout political, economic, and financial systems (Hart and Milstein, 2003; Rubin and Esty, 2010; WEF, 2019). The need to revolutionize our food systems is embedded in many of the UN Sustainable Developments Goals (SDGs), particularly calls to end hunger (SDG2), to ensure healthy lives (SDG3), to achieve sustainable consumption and production (SDG 12), to combat climate change and its impacts (SDG13) , and to conserve life on land (SDG15).

Figure 6: Meeting Dr Karen Fabbri, DG Research (6a) and Alison Graham, ICOS (6b) in Brussels with fellow 2019 Scholar, Alison Homes.

6a   6b

12.3 New Zealand

With a population of just under 5 million, New Zealand's primary industry sector is a critical component of the economy, accounting for more than 78 percent of product exports (MPI, 2017). Approximately 52 percent of New Zealand's land is farmed, and similar to Ireland, most of this land is in grassland. Recent statistics (Beef and Lamb New Zealand, 2019) report 34.1m sheep, 4.1m beef and 5.6m dairy animals across 23,403 sheep/beef farms and 11,100 dairy farms. The dairy sector remains a key part of the economy ($15bn in exports) and Fonterra is the largest company and cooperative (owned by 10,000 farmers) in New Zealand processing 15.5bn of the 21bn litres of milk (80% approx.) produced. As in many parts of the world, the agri-food sector in New Zealand is experiencing significant challenges, particularly around environmental sustainability. The current proposed Essential Freshwater Bill, jointly developed by primary sector representatives, Regional Councils and the Ministries of Environment and Primary Industries is focussed on the reducing the impact of agriculture on fresh water. There is a general apprehension amongst farmers and wider industry that the requirements proposed in the Bill could fundamentally alter the principles of New Zealand's pasture-based production systems.

On an annual basis, there is approximately $4bn invested in R&D in New Zealand, with Government investing $1.6bn and $2.4 bn invested from industry (Evans, 2019 per comms). This equates to approximately 1.3% of GDP, with a future target of 2%. Statistics New Zealand undertake the Research and Development Survey providing information about R&D expenditure from Government, business and higher education. This was last done in 2018 and showed a high level of public and private investment in primary sector science. About 25-30% of total public research funding goes towards the primary sector (includes primary, food and beverages sectors and relevant environmental research). Together, industry and government invest approximately $800m in primary sector science ($430m of public funding and approximately $400m from industry).

Meetings with MPI and researchers at Massey and Lincoln Universities, Agresearch and DairyNZ, highlight that key research priorities relate to the environmental sustainability of the sector with significant resources focussed on nitrogen use efficiency (NUE), climate change

and greenhouse gases (GHGs). Other areas of focus include, people in agriculture and the effective use of new technologies in dairy systems and the integration of the data generated into farm decision making.

New Zealand's future plans for science and technology are outlined in the Primary Sector Science Roadmap (MPI, 2017) and is part of the Government's overall strategy for the science system, which is set out in the National Statement of Science Investment 2015–2025 (MBIE, 2015). The Roadmap was developed in response to growing concern that there was no widely shared view of future science and technology capability needs and opportunities across the sector. The intention is that the Roadmap will give direction to strategy and investment decision-making by funders, research and development providers, industry, and government departments. It highlights eight key themes for future science and technology necessary in order to increase the value derived from the primary sector. Sustainable growth in productivity and profitability, including significant growth in product value is highlighted, as is the need for product diversification and the necessity to respond to challenges such as those of climate change, biosecurity, food safety, the health of soils, freshwater and marine environments. Specifically, areas such as genetics and genomics, improved animal/system efficiency, animal health and welfare and resource management will be prioritised. The lack of resources in the extension services in New Zealand is also to be addressed.

Figures 7: Visiting Massey University Dairy Farm (7a) and Dairy NZ, Hamilton, New Zealand (7b)

7a   7b

12.4 Australia

Agricultural activity is very variable across Australia and is determined by climate, water availability, soil type and proximity to markets. Livestock grazing is widespread, occurring in most areas of Australia, while cropping and horticulture are generally concentrated in areas relatively close to the coast. The top three agricultural commodities produced nationally ranked by export value in 2018-19 were: Cattle and calves ($9.485 billion), Wool ($4.159 billion) and Wheat ($3.676 billion). The dairy industry is in decline in Australia, with national milk production now at 8.8 billion litres, down more than 10 per cent since 2008-09. The number of dairy farmers has also decreased from 8000 to just over 5000 over the same period (Australian Bureau of Statistics, 2020). The gross value of Australian agriculture was $62.208 billion in 2018-2019 and of this, 79 percent ($49.2 billion) was exported (National Farmers Federation, 2020). Agriculture, forestry and fisheries accounts for approximately 2.5% of the national workforce in Australia and of the 394 million hectares of land operated by agricultural businesses in Australia, 87 percent (341 million hectares) are used for grazing. China is Australia's single largest export market for agriculture, fisheries and forestry at close to $14 billion in 2017–18 (Australian Bureau of Statistics, 2020).

From a research perspective, the huge variation in climate and agricultural systems in Australia poses significant challenges for research and researchers. Research needs to be region-specific as the needs are very different, even within individual states. Compared to Ireland and New Zealand, there is less of a focus on the environment and animal welfare. Prof Eckard in Melbourne University, an expert in the area of climate change and animal agriculture, highlighted the difficulty of political involvement in research strategy. The current Australian Government does not believe in climate change and this is a proving to be a very difficult situation for researchers and research programmes in this discipline.

Possibly due to the variation in agricultural production across Australia, there appears to be a lack of collaboration amongst research organisations to tackle big issues facing the agri-food sector. The need for long-term systems research was evident, incorporating work on heat stress, grass/plant suitability and survival, impacts of climate change on feedstuffs and animal welfare in different regions. It will take collaboration among many actors to make this happen. The research programme at Ellinbank Research Centre in West Gippsland, Victoria Australia

(Argyle, 2019 per comms) plans to tackle some of these issues through the development of a 'future farm system' evaluating automation, sensor and dashboard technologies to improve the health of cows and people on the farm. This technology should also result in better NUE, lower GHGs and ultimately lead to carbon neutrality.

Future focussed research areas will also include grass breeding and gene editing as grass breeding technologies will be key to Australia remaining a grass-based industry given the extreme drought conditions being experienced on an ongoing basis. Climate variability is driving up costs of dairy production on farm and future research programmes need to refocus on lower costs of production. Dr Kevin Argyle stressed the need for greater inclusion of social science at an earlier in the design phase of research programmes to help future proof research and technologies.

Figure 8: Harper and Oonagh Kilpatricks Farm, West Victoria (8a) and visiting Agribio, Melbourne, Australia (8b).

8a   8b

12.5 What are the Future Research Needs?

Agriculture faces significant challenges in the coming decades. It must produce more food for a growing, increasingly affluent global population, while competing for access for increasingly scarce natural resources, preserving biodiversity and water quality, mitigating the effects of climate change and adapting to new plant and animal disease threats.

Science and technology accelerates innovation and growth for economic and environmental sustainability of the sector and therefore, a national policy to give direction to strategy and investment decision-making by funders, research and development providers, industry, and government departments is critical. In such as exercise, we need to be alert to disruptive change. This could be in the form of mounting pressure to move to more plant-based food production systems, away from livestock, because of GHGs, water quality and animal welfare concerns. Research on biofuels and biorefineries, alternative foods, carbon economy and greater diversity in production systems could lead to opportunities in Ireland that are not currently being considered. To make these sorts of shifts, we need to ensure that we have the science necessary to provide evidence for decision- and policy-making and increase our competitive advantages in global trade, improve profitability, and ensure that our production systems are environmentally and socially acceptable.

A balance between the immediate and medium-term RD&I needs and the longer-term strategic requirements must also be achieved. There was broad agreement with the stakeholders consulted in this study that there is currently too much focus on solving immediate problems and as a result, we are not sufficiently considering future issues and opportunities that may arise and therefore not adequately preparing the industry. Research shows that the impact pathways for agricultural research are long: on average, 19 years elapse between the beginning of a project and the manifestation of its impacts (McEldowney, 2019).

Levy funded research is a very important source of funding for applied research in many countries including Ireland. David Williams, National Milk Supply Manager, Synlait and Duncan Coull, dairy farmer and recently retired council member of Fonterra question if those

making the RD&I decisions are too invested in the sector to ask the difficult questions? The experience in New Zealand is that levy funding has been very focussed on production increases and not enough on strategic areas to attempt to future-proof the industry against certain threats. Examples of nitrate leaching in the South Island of New Zealand as a result of dairy expansion and the issue of male calves from the dairy herd were highlighted as key issues for the industry and where a more consultative, strategic approach in planning research may have avoided some of the problems experienced currently.

Any future strategy must also incorporate basic/fundamental or curiosity-driven research that will give us important opportunities that cannot yet be anticipated. Science priorities that push the boundaries of knowledge must be directed by our understanding of future needs. Integrating scientific knowledge with good communication, business, market intelligence, management and policy will help ensure a future we all want. Consumer trust in food science and technology will strengthen as these become vital tools to save our food supply (Mintel, 2019).

Research, Innovation and the Bioeconomy are forming a critical part of the Agri-food 2030 strategy alongside other key issues such as responding to changing consumer demands, farmer viability and wellbeing and environmental sustainability (Tom Arnold, 2020 per comms). Tom Arnold believes that food systems should actively encourage nutritious and healthy food and that decisive and urgent action is required in the interconnected policies of food, health, and climate. Agri-food research priority areas for the coming decade should focus on reducing GHG emissions in food production, increasing carbon sequestration through changes in land use and renewable energy generation, and the promotion of diversification and biodiversity. In line with the EU Farm to Fork Strategy (European Commission, 2020) and CAP policy, there will be an increased focus on ag-tech and agri-digitilsation. The agricultural sector in Ireland and globally is increasingly becoming more technologically advanced. Technology promises improved productivity and quality, increased efficiencies, reduced wastage and enhanced sustainability - and the ability for industry and farmers to make better decisions. This in turn should lead to better economic benefits on-farm, in the wider agri-industry and as a consequence, in our rural communities. Aidan

Connolly (2020, per comms), CEO of Cainthus believes that the future focus should be on precision agriculture to improve sustainability, increase efficiency, improve animal welfare and reduce carbon footprint. Achieving carbon neutrality is going to require a significant change in how we farm and produce food.

13. Pathways Towards a Sustainable Agri-Food System

13.1 Introduction

Earlier chapters have outlined the research landscape in Ireland including the main funding agencies and research performing organisations. The current and future focussed research priorities in Ireland and other major agri-food producing countries visited as part of my Nuffield study have also been summarised. It is clear that RD&I must form a critical part of a sustainable agri-food system and this chapter will explore ideas, key concepts, actions and actors required for the development of a future focussed research and innovation agenda.

13.2 Diversity of Thought and Skills - Getting the right people around the table

We must ask the difficult questions and face up to difficult issues, even if they are unpalatable. Doing this effectively requires a diversity of voices and capabilities around the table inputting into future strategies and decision making. What are the key objectives for ongoing and future RD&I? Should we be building critical mass in certain research disciplines or centres of research or spreading the resources? What are the outputs of the research over the last 10 years? What impact have they had? How is this impact measured? What is the relationship between the agri-food research system and the broad societal issues we have to address such as health and wellness, climate change, waste, animal welfare? What is the connectivity across the agri-food value chain?

Professor Hamish Gow, Professor of Agribusiness at Massey University advocates that we need to rethink how we think. Experts in individual disciplines start with the solutions and then look for a problem to solve. It would be far more beneficial if we spent more time defining the problems. A greater focus is required on signals, insights, uncertainty and experimentation and this will require input and collaboration from a broad range of actors. Agri-food RD&I will form part of the upcoming Agrifood 2030 and Patrick Barrett, Research and Codex Division, DAFM, discussed a changed approach, cognisant of the need for better

cohesion and coordination of efforts to solve the grand challenges and incorporating greater engagement with stakeholders, social scientists and civil society through mechanisms such as policy labs.

13.3 Identifying Knowledge Gaps

As discussed in Section 11, there are a significant number of organisations funding agri-food related RD&I in Ireland. It was difficult through the course of this research to get clarity on the key research priorities, who is doing what, where the work is happening and the level of investment of public funds in particular areas. A central database with this information would be extremely useful to researchers, RPOs and indeed to companies engaging in agri-food RD&I. Knowledge Transfer Ireland (KTI) is the agency responsible for helping companies navigate the complex RD&I landscape in the sector to ensure they engage actively to improve competitiveness and increase growth (Campbell, 2020, per comms). Knowledge Transfer Ireland is therefore an appropriate place for the collation of this information, however, Alison Campbell, Director of KTI, cited a lack of resources as the main reason why such a resource does not currently exist.

Without knowing the current state of play, it is difficult to ensure that minimal duplication is occurring and perhaps more importantly, it is very difficult to identify gaps in knowledge to inform future RD&I programmes. With an increasing number of RPOs engaged in agri-food RD&I, this task will become increasingly complex in the future.

13.4 Rethinking the System – Alternative Approaches to the Research and Innovation System in Ireland

13.4.1 A Mission Led Research Approach

The research by Mariana Mazzucato (Professor at University College London in Economics of Innovation and Public Value) focusses on the relationship between innovation and the direction of growth, with emphasis on rethinking the public sector's role to ensure growth is more innovation-led, inclusive and sustainable (Mazzucato, 2018). She advocates 'mission orientated' policies, which aim to steer solutions towards grand challenges i.e climate change, health and wellness. Mission-oriented policies can be defined as systemic public policies that draw on frontier knowledge to attain specific goals or "big science deployed to meet big problems" (Ergas, 1987). Missions provide a solution, an opportunity, and an approach to address the numerous challenges that people face in their daily lives. The mission-led approach advocates that policy development should involve a wide array of stakeholders, each contributing to key questions such as: What are the key challenges facing society; How can concrete missions help solve those challenges; How can the missions be best designed to enable participation across different actors, bottom-up experimentation and system-wide innovation?

Global challenges have been expressed as 17 SDGs. The SDGs are useful to ensure focus, however, they are very difficult to action because they are so broad. On the other end of the spectrum, RD&I projects have clear objectives and are actionable, but will remain isolated in their impacts if not clearly linked to their ability to address global challenges and to achieve societal impact. Missions should be broad enough to engage the public and attract cross-sectoral investment, yet remain focussed enough to involve industry and achieve measurable success (Mazzucato, 2018).

Figure 9: Illustrating the movement from broad challenges to specific missions (Mazzucato, 2017)
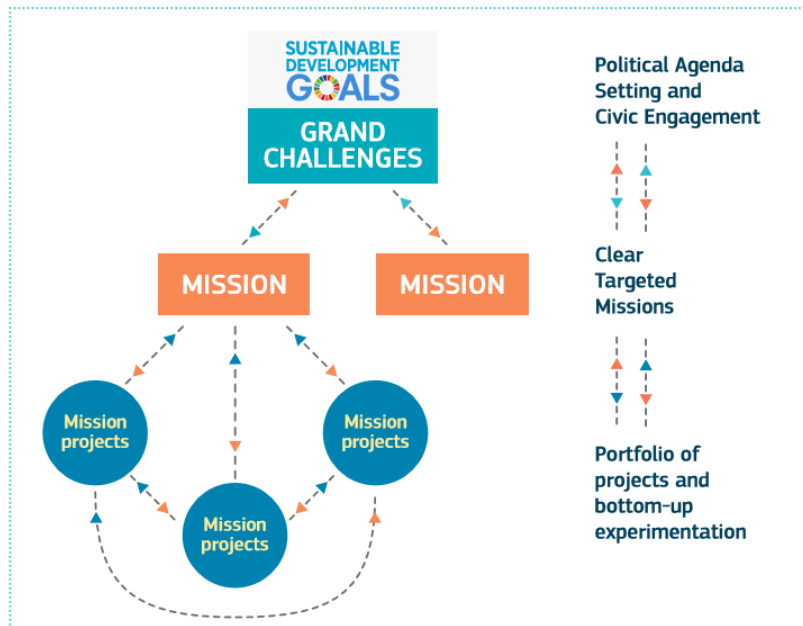
Such an approach to refocus RD&I efforts in Ireland has been proposed by the High-Level Innovation Committee as part of FoodWise 2025 and also by DAFM in the upcoming Agri-Food 2030 strategy.

13.4.2 UK Research and Innovation (UKRI)

UK Research and Innovation brings together the seven Research Councils, Innovate UK and Research England and operates across the whole of the UK with a combined budget of more than £7 billion. UKRI works in partnership with universities, research organisations, businesses, charities, and government with the aim of creating the best possible environment for research and innovation to flourish. The ambition of UKRI is to create the world's best funding organisation for research and innovation and promote interdisciplinary research and research integrity. Currently the UK target is 1.8% of GDP on RD&I with ambitions of 2.4% by 2027. UKRI have been engaging with Stakeholders through workshops, to explore some of the biggest questions for UKRI, and the UK R&I landscape more broadly over the coming years. Each workshop gathered experts from across business, academia, policy and research to explore key aspects such as: lessons learned from previous attempts to increase RD&I investment and international comparisons; how to maximise impact; how to grow the

economy regionally while continuing world-leading excellence in R&I and how to enhance the UK business environment for R&D. Workshop outputs are being used to develop an evidence base and inform policy and analysis work and for each, a short summary of the discussion and delegate list is published on the UKRI website. Transparency like this could help to build public/consumer confidence in RD&I strategies.

Prof Nigel Scollan, Queens University, Belfast discussed the UKRI model as a means of improving coordination and cooperation of research activities in the agri-food area. Tackling grand challenges requires collaboration amongst many actors and such an approach might be beneficial for Ireland also. By bringing the organisations together under one umbrella, efficiencies in administration can be gained. Prof. Scollan also stated that the continued reduction in public sector funding for RD&I will increase the importance of private industry funding. However, investment in RD&I by agri-food sector is the lowest of all sectors in the UK, partly due to the fact that the UK is not export driven.

13.5 Involving Civil Society in Research and Innovation Policy for Greater Acceptance and Impact

13.5.1 Health Research Board - Patient and Public Involvement in Research

There is an increasing international interest in patient and public involvement (PPI) in health related research, as it is thought to improve the way the research is prioritized, commissioned, undertaken, communicated and used. Active involvement of service users in research can lead to research of greater quality and relevance owing to the unique perspective that users can bring to a research project (Entwhistle et al., 1998). Public and patient involvement occurs when the public/patients work in partnership with researchers in setting priorities for research, in planning and managing research studies, as well as in summarizing, distributing, sharing, and putting results into practice (Brett et al., 2012).

The HRB has put together an implementation plan to support PPI both within the HRB and through HRB-supported projects and programmes (HRB, 2019). The aim is to involve the

public, who are not researchers, in health-related research and for the public to help shape and guide the research. The HRB aim to create an active partnership between the public and researchers, with the voice of the public contributing throughout the research process.

13.5.2 Policy Labs

Policy Labs are spaces designed to foster creativity and engagement, and to develop interactions, processes and tools able to bring innovation into policy-making. Policy Labs were used in FIT4FOOD2030, a project funded to support the EC to further develop and implement the FOOD2030 policy framework action plan. FOOD2030 was an ambitious policy initiative by the EC to support the UN SDGs. The Irish Government, through DAFM and DBEI (Enterprise Ireland) supported the Fit4Food2030 project by running a policy lab. The aim of the policy lab was to further support the transformation of R&I on FNS in Ireland and Europe. A similar approach to inform future food systems R&I policy is being advocated by DAFM (Barrett, 2020 per comms).

13.6 Public and Private Collaboration to Tackle the Grand Challenges

Meaningful collaboration is needed more than ever to tackle the grand challenges that face the global agri-food sector. Collaboration is required to understand and integrate the diverse new sources of knowledge and data that will drive new services, systems and management practices across the food system (Negra et al., 2020). There is a need for deep disciplinary knowledge, along with transdisciplinary, critical thinking and problem-solving skills to enable sustainable growth and to address policy and regulatory issues that arise in response to the concerns of consumers in Ireland and in export markets. True solutions, with positive social impact, require working across and beyond traditional boundaries that often separate natural scientists, technologists and engineers from social scientists. Scientific findings do not move freely across poorly connected sectors and therefore fail to provide decision makers (public and private) with clear information on how to improve system-level sustainability (Liu et al., 2017). In agreement with this, Richard Kennedy, CEO of Devenish believes that effective

collaboration is necessary to deliver 'real' sustainability. However, he feels that while public private partnerships will be key to solving many of the grand challenges facing the sector, true collaboration is unfortunately often lacking (Richard Kennedy, 2020 per comms).

While they are more likely to be fit-for-purpose, sustainability RD&I programmes and policies developed through multi-sector collaboration may be vulnerable to perceived or actual bias toward contributing companies and financial institutions. Indeed, the general view of the 'civil society mechanism' attending the FAO UN CFS meeting in Rome showed a deep mistrust for many science and technology solutions proposed as a means to solving global challenges, particularly where private industry funded or co-funded the research. This raises obvious questions about the value of the significant public and private investment in RD&I if the results of that research are not trusted or are largely ignored. The communication and translation of science to consumers has never been more important. Solutions to the growing divide between primary food production and civil society lies in increased transparency to build trust and continued dialogue focussed on the common goal of sustainable food production. Recent research from Mintel (Mintel, 2019) indicates that from 2020-30, consumers will become more accepting of, and trusting in, the essential role science and technology play in guaranteeing access to affordable, safe and nutritious food and drink.

13.7 The Netherlands

Second only to the U.S. for agri-food exports worldwide, the Netherlands has more than 5,300 companies in the agri-food sector (FoodValley, 2020). In fact, 12 of the world's largest agri-food companies have major production or R&D sites there, including Cargill, Heinz, Unilever, Mead Johnson, ConAgra, Mars and many more.

The Netherlands are leaders in agri-innovation and remain focussed on continuing this trend but with an increasing focus on the bio/circular economy and food system sustainability. Developing climate neutral, sustainable and robust production systems, where circularity and reuse of waste and by-products are embedded is where research is focussed. Prof. Martin Scholten believes that these goals can be achieved in tandem (Scholten, 2018, per comms).

Fuelled by world-class research institutes for food innovation and numerous public-private partnerships between science, industry and government, the Netherlands has the 2nd highest private R&D investment in agri-food in Europe (FoodValley, 2020).

Dairy Campus, Leeuwarden

Dairy Campus is part of Wageningen University & Research, but is also linked with organisations such as Van Hall Larenstein university of applied science, vocational education Nordwin College, national farmers organisation LTO Nederland, dairy co-op FrieslandCampina, RUG Campus Fryslân, city of Leeuwarden and the province of Fryslân. Dairy Campus is part of the national agri-food cluster and connected also with other Dutch clusters like Food Valley Wageningen, Water Campus Leeuwarden and the Sino Dutch Dairy Development Centre in Beijing - China.

The focus at Dairy Campus is to conduct innovative projects and activities in order to generate new information and knowledge to drive innovation in the dairy chain. Close cooperation with entrepreneurs and the business sector is key to success. The focus and direction of research are mapped out in a 4-year Strategic Plan (2019-2022). Wageningen University and Research has identified five scientific research programmes around climate, biodiversity, food production, healthy and safe nutrition and the circular economy.

13.8 Towards a Sustainable Agri-Food System

The RD&I system has a key role to play in providing solutions to transform the food system into more sustainable, resilient, responsible, diverse, competitive and inclusive pathways. However, from my studies it is evident that in order to achieve the ambition of a sustainable agri-food system, there needs to be greater cohesion, collaboration and communication amongst all actors and organisations within the system. Figure 10 outlines key concepts and actions required in the development of a future focussed research and innovation agenda.
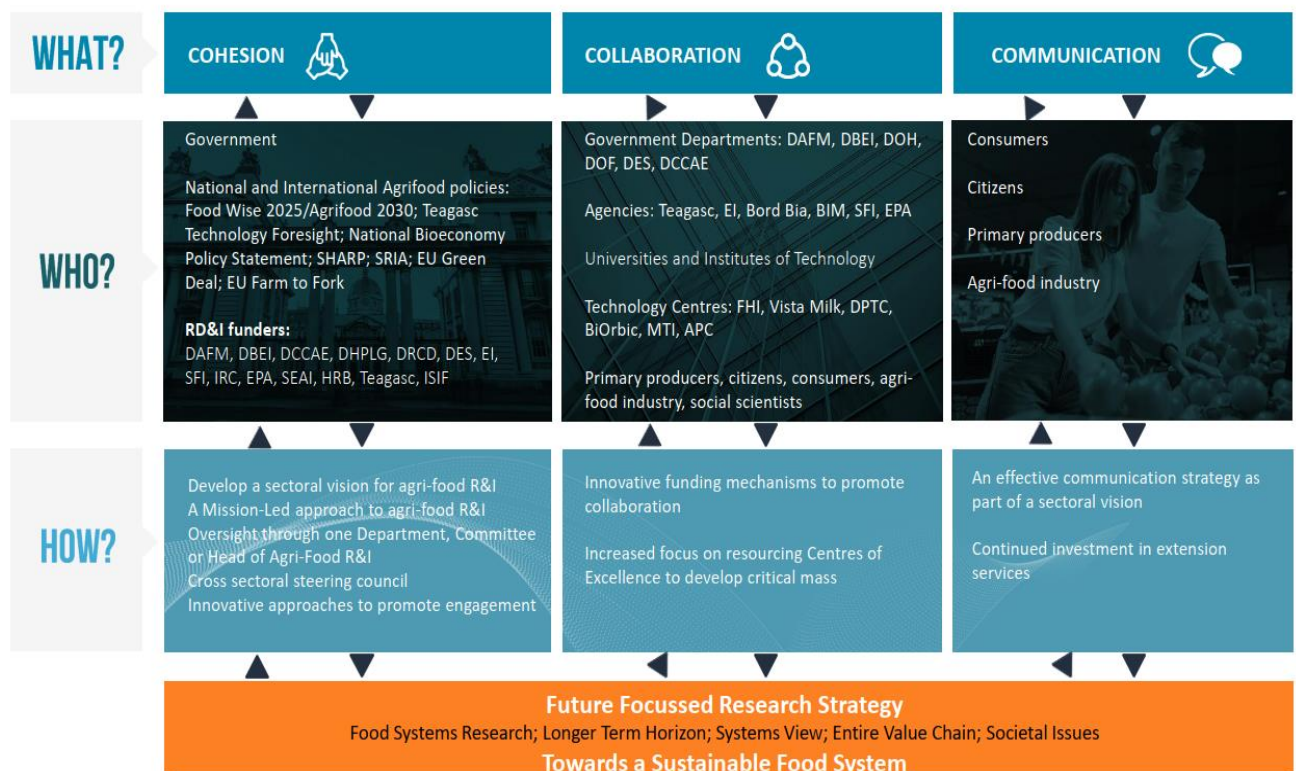
Cohesion: Cohesion between Government, the various national and international agri-food policies and funders of RD&I is a critical first step in the development of a future focussed research and innovation agenda. This could be achieved through having more coherent

oversight through one Department, Committee or a Head of Agri-Food R&I. A cross sectoral steering council could also ensure greater engagement across the entire sector. Combined with innovative approaches such as policy labs and PPIs, enhanced engagement with the wider industry and increased 'buy-in' from wider society into research and primary food production in general could be achieved. An effective communication strategy as part of a sectoral vision would also be critical to ensure that all actors are informed.

Collaboration: Solving the problems within the food system will require meaningful collaboration amongst all actors involved including the main Government departments and agencies, Universities and Institutes of Technology and the SFI, DAFM and EI funded Technology Centres. In combination with this, involvement from primary producers and the wider agri-food industry will be critical as will insight from social scientists. While more difficult to obtain, insights from citizens and consumers will help to future proof any RD&I strategy. Achieving this could be aided through innovative funding mechanisms that promote meaningful collaboration.

Communication: While often lower down priority list, communication is vital to the success of any strategy and this communication needs to be focussed both towards those working within the agri-food industry and also to the wider public. Communication would be easier if there was a single sectoral RD&I strategy document for the industry with a communication strategy built around that. A lead Department, Committee or Head of Agri-Food R&I to coordinate this would also improve communications efforts. From a primary production perspective, continued investment in extension services is essential to communicate research findings with farmers and ensure that research does not move too far ahead of practice and converse to that, where farmers are innovating, that this is fed back to researchers to inform future research priorities.

Figure 10: Cohesion, Collaboration and Communication. Key concepts and actions required in the development of a future focussed research and innovation agenda

WHAT?	COHESION	COLLABORATION	COMMUNICATION
WHO?	Government National and International Agrifood policies: Food Wise 2025/Agrifood 2030; Teagasc Technology Foresight; National Bioeconomy Policy Statement; SHARP; SRIA; EU Green Deal; EU Farm to Fork **RD&I funders:** DAFM, DBEI, DCCAE, DHPLG, DRCD, DES, EI, SFI, IRC, EPA, SEAI, HRB, Teagasc, ISIF	Government Departments: DAFM, DBEI, DOH, DOF, DES, DCCAE Agencies: Teagasc, EI, Bord Bia, BIM, SFI, EPA Universities and Institutes of Technology Technology Centres: FHI, Vista Milk, DPTC, BiOrbic, MTI, APC Primary producers, citizens, consumers, agri-food industry, social scientists	Consumers Citizens Primary producers Agri-food industry
HOW?	Develop a sectoral vision for agri-food R&I A Mission-Led approach to agri-food R&I Oversight through one Department, Committee or Head of Agri-Food R&I Cross sectoral steering council Innovative approaches to promote engagement	Innovative funding mechanisms to promote collaboration Increased focus on resourcing Centres of Excellence to develop critical mass	An effective communication strategy as part of a sectoral vision Continued investment in extension services

Future Focussed Research Strategy
Food Systems Research; Longer Term Horizon; Systems View; Entire Value Chain; Societal Issues
Towards a Sustainable Food System

14. Conclusions

The overall aim of this study was to evaluate if the future needs of Irelands agri-food sector are being addressed through current research. This scholarship has given me an amazing opportunity to travel the world, to broaden my perspective, to challenge myself and open my mind to many different types of agricultural systems around the world. As a result, it has given me a greater appreciation of the opportunities and challenges faced by the Irish agri-food sector.

Below are the key conclusions from the study:

- The RD&I system has a key role to play in providing solutions to transform the food system into more sustainable, resilient, responsible, diverse, competitive and inclusive pathways

- The Irish agri-food sector, when benchmarked against its global competitors, underperforms in terms of RD&I expenditure. To successfully compete in global markets, there is a need for greater investment by the industry in RD&I to close the gap with our competitors

- Given the significant public investment in RD&I, better coordination is necessary to ensure greater value for money, reduce duplication and identify gaps in knowledge to effectively plan future-focussed RD&I programmes

- To be transformative, there needs to be a move from component type research to a more systems approach that incorporates all elements of the food chain, from primary production through to the health and behaviour of consumers.

- There needs to be a major focus on fostering a collaborative environment around key industry issues. While there is significant public investment in agri-food RD&I, there have been missed opportunities to align investments across the range of funds and funders in our science system.

- Strong partnerships between industry, policy-makers and research providers will be required to ensure that science is translated into strong business, policy and management decisions.

- Strategic or basic research, while involving greater risk, are necessary to better prepare the sector for upcoming challenges
- The increased requirement for private sector funding in major research programmes may increase the utility of the research among those companies, however an effective communication strategy is critical prove transparency and build trust with consumers
- The research system needs to capture wider stakeholder opinion in the planning phase to help identify possible issues (public/consumer for example) at an earlier stage
- Most research is focussed on short to medium term issues and there is not enough focus on longer term, strategic issues. In this regard, levy funded research is very focussed on immediate concerns, but as a vital source of funding for applied research, there needs to be a greater allocation of funds to strategic areas of research

15. Recommendations

- There is a need for a national research and innovation policy to give direction to strategy and investment decision-making by funders, research and development providers, industry and government departments

- This national policy should be inclusive of the entire food system and incorporate a broad range of views to tackle 'grand challenges'

- A 'mission led' approach could be beneficial to ensure that funded research is targeted to solving the grand challenges facing the Irish agri-food industry

- Given the current pressure on animal agriculture, greater investment into research and innovation linking primary food production, nutrition and health is necessary

- Greater oversight and coordination through a single Government Department or committee, or by appointing an Head of Agri-food RD&I would improve cohesion across the system

- As the requirement for private sector funding in RD&I increases, a communication strategy is necessary to build consumer trust and ensure utility and impact of the research

- While carrying greater risk, an increased focus on strategic and basic research is necessary to future-proof the sector

- Greater investment in longer term systems type research is necessary to build capacity in key areas and truly evaluate the long-term impacts of the research and innovation implemented on the whole system, including societal, environmental, productivity and financial aspects

- Continued investment in extension services is critical to avoid research moving too far ahead of practice

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