Climate-KIC

Co-funded by the European Union

An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

Dealing with Climate Change and Sustainability Targets

The innovation potential for the Irish Agri-Food Sector

Editor | Saskia Visser

Amsterdam | March 2023

climate-kic.org

Contents

Executive Summary

Background

In order to help the sector deliver on accelerated pathways for climate action and food system transformation, the Irish Department of Agriculture, Food, and the Marine (DAFM) has partnered with EIT Climate-KIC – Europe's largest climate innovation partnership — to support national climate action in the agriculture and food sector. Building on EIT Climate-KIC's Deep Demonstration methodology, the two-year initiative will develop and initiate a portfolio of innovation actions across the entire value chain, from soil to farm to fork.

This report, *'Dealing with climate change and sustainability targets'*, provides an overview of solutions that can be considered as a part of the portfolio development, during which new innovation actions — including both policies and projects — are co-designed with public, private and civil society stakeholder actors.

Ireland wants to become a world leader in Sustainable Food Systems over the next decade—a transition that will require significant transformation.

The agrifood sector is Ireland's oldest and largest indigenous industry. It is a substantial employer and contributor to the economy — employing over 170,400 people (7.1% of total employment) — and is deeply ingrained in Irish society and culture. Ireland also prides itself on its green, family farm image and a reputation of selling high-quality, sustainable produce. This image is a powerful part of the Irish Food and Drink Brand and contributes significantly to Ireland's ability to export about 90% of its production.

Reconciling Ireland's sustainability ambitions with its plans to grow the value of the Land-Agri-Food sector while also producing food within the island's planetary boundaries will require a shift in focus from volume of production to value of production. This will be a significant transition and will inevitably result in trade-offs that need to be reconciled with stakeholders across the system.

The Irish government has set ambitious goals for its Land-Agri-Food sector through its Climate Action Plan and the Food Vision 2030 Strategy: reducing emissions by 25% by 2030 and achieving climate neutrality by 2050. To reach these goals, new and innovative approaches will be required by all stakeholders.

A wealth of climate-positive solutions is available for Irish Land-Agri-Food stakeholders to trial—from new and innovative to well-established practices.

Ireland can draw on a wide array of innovative solutions from circular and bioeconomy practices, carbon farming, alternative proteins, and nature-based solutions to achieve the goal of a sustainable food systems. These solutions have significant climate mitigation potential, alongside multiple co-benefits for resilience, biodiversity, climate adaptation, water and air quality and economic sustainability.

The solutions explored in this report are outlined below, with corresponding chapter numbers where more information can be found.

Chapter 1: Dealing with climate change

The Irish Land-Agri-Food system is complex and requires multiple systemic changes to meet its climate goals. Instead of using technology, tweaking current production systems to achieve mild carbon efficiency gains per product, while production volumes continue to rise and outweigh the emission gains, nature-based solutions provide a pathway towards new, regenerative production systems.

Adopting natural fertilisers (for example, green manure and compost) and locally sourced livestock feed (for example, through silvopasture, rotational grazing and using sideflows from food production) have a regenerative impact on soil health and biodiversity and cut the emissions involved in the production and transport of the artificial inputs, since they are produced from renewable sources.

Key solutions include: i) extensive ruminant farming (with reduced herd size), ii) methane-reducing feed additives for ruminants, iii) plant-based production systems, iv) nitrogen from crop system diversification and N-fixing plants, v) agroforestry, and vi) paludiculture (rewetting peatlands).

Policy recommendation

When considering effective measures to mitigate the Land-Agri-Food sector's carbon emissions, while also generating co-benefits regarding other urgent challenges - in this case water and air quality - two guiding principles are key.

1. Firstly, taking a food system approach in order to reconsider ***what*** is produced and ***why.*** It is essential to first consider the carrying capacity of Ireland's soil-water systems and the climate goals, when (re-) designing future-fit food production systems. Moreover, considering the interactions and effects of the multiple levels of food systems - production, processing, distribution and consumption - is key to ensure food and nutrition security, equitable value chains, and positive environmental outcomes.
2. Second, the guiding principle of nature-based solutions as a preferred range of measures before more technology-based solutions. Nature-based solutions already exist and require relatively low investment in innovation—just smart implementation of nature's best 'technologies' into well-designed new Land-Agri-Food systems.

Chapter 2: Carbon-farming

Carbon farming is a 'green' business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall.

This chapter provides an overview of current knowledge on carbon farming and provides some recommendations for the development of a national carbon framework. The recommendations include: i) providing a good baseline, ii) training of farmer advisors on carbon farming practices, iii) setting up an (inter) national standard for Measurement, Reporting, and Verification (MRV) of Carbon Credits, iv) minimising administration, v) making sure matchmaking between supplier of and demand for carbon credits is organised, vi) facilitating locally adapted governance to support scaling.

Policy recommendation

Ireland's Climate Action Plan 2023 recognises that carbon farming can play a central role in encouraging the changes necessary to reduce greenhouse gas (GHG) emissions and to support additional environmental benefits. An enabling carbon framework is due to be developed by Q4 2023. We recommend to:

- Closely follow what is going on in Europe, to assure the national framework is in line with the European framework, to assure long-term success of the national carbon market.
- Develop a flexible framework, that allows adoption of new insights, methods and financing mechanisms from innovations currently under development which may enrich the Irish framework .

Finally, we recommend to explore the potential to extend carbon credits to nature credits, not only funding for carbon, but also the inclusion of other sustainability indicators like biodiversity. This supports farmers through payment for actions implemented and avoids negative trade-offs for other eco-system services.

Chapter 3: Alternative proteins

In a sustainable Land-Agri-Food system there is ample opportunity for the development of a market for alternative proteins. Ireland has the potential to offer an interesting contribution to alternative proteins for both human food and as feed additives. Interesting markets that can be developed are those of: i) Plant-based and ocean-based alternatives for human nutrition, ii) Feed additives; especially where it delivers methane reduction, iii) Circular feed production in which fungi, insects, algae, fish cut offs and seaweed have an important role to play and iv) The role of grass as a protein source can also be further explored.

The Irish government policy for a sustainable, smart Land-Agri-Food sector, together with its ability to coordinate across Departments, together with the shift to a Challenge-Focused Innovation System, offers a unique opportunity to mobilise finance and develop an entirely new sub-sector within Irish Land-Agri-Food.

Policy recommendation

To fully benefit from the potential of an emerging market for alternative proteins for both food and feed, it is important to develop a **policy supported protein strategy**, which also includes the ambition to reduce animal-based proteins in the diets. The strategic plan to support native protein production form the Irish protein stakeholders group provides a good start.

A **cross government** strategy on alternative proteins is needed to stimulate the production of either plant based, ocean based and/or circular proteins for food and feed and to align to agendas for the tillage, marine, and livestock sectors.

The protein strategy will support a compelling investment case in a sustainable system pathway, with identified and de-risked returns, that helps accelerate the deployment of third-party capital.

Chapter 4 & 7: Circular Economy

While traditionally linked to waste management and the more downstream parts of the value chain, circular economy solutions actually takes a full systems perspective and overlaps with many of the solutions in the Land-Agri-Food systems. They can be broadly grouped into:

- Regenerative and, where appropriate, local food production practices (e.g., agroforestry, cover cropping, crop rotations and other nature-based solutions).
- Social and technological innovations to shift towards low-impact and healthy consumer diets (that are high in plant-based and whole foods and low in animal and processed foods), including but not limited to investing in alternative proteins.

- Social and technological innovations to design waste out of food and food packaging (including food loss and waste prevention and reduction solutions, industrial symbiosis, reusable packaging business models and more).

Together, these have high climate mitigation potential, can support biodiversity conservation—and even help reverse ecological overshoots.

The changing regulatory framework surrounding plastic packaging, and in particular single use plastics represents a major business opportunity for Irish companies, on the production side and on the use side.

Apart from offering greater sustainability, biobased packaging and other innovative packaging solutions often provide additional functional benefits which make them more attractive.

Circular economy principles offer a potential solution to tackle food waste, by repurposing residues and changing thinking away from traditional linear based production systems to a more regenerative and self-sufficient system. Producers and retailers play a fundamental role in tackling food waste issues, stricter regulatory measures could incentivize more effective solutions being developed to minimise food waste across the value chain.

Policy recommendation

Action plans in Ireland already cover key circular economy topics such as food waste prevention and reduction. Still, more emphasis could be given to moving beyond end-of-life solutions and to prioritising reducing impacts at the source and the regeneration of nature.

Specifically, policymaking could address the following 'gaps':

1. Providing support to farmers in adopting nature-based solutions as a preferred range of measures over technology to realise carbon-neutral primary production systems
2. Encouraging greater collaboration between stakeholders (e.g., via industrial symbiosis or the piloting of reverse logistics systems for packaging)
3. Acknowledging the role of consumer diets in driving environmental outcomes and shifting consumer norms accordingly
4. Reducing packaging and investing in the development of reusable, recyclable and biobased packaging materials
5. Develop the infrastructure to develop the market for alternative packaging by i) facilitating connections with solution providers, ii) providing clear labelling guidelines, and iii) supporting the development of additional waste management infrastructure.
6. Facilitate knowledge sharing and awareness building to educate industry and citizens on the negative environmental and societal consequences of food waste.

Chapter 5: Meat and dairy processors' role in influencing supply chain

Currently, Ireland is a key player in the European meat and dairy processing sectors, yet these sectors face significant challenges when it comes to realising sustainability goals. Current plans rely largely on the uptake of technological innovations to provide the necessary emission reductions and could be broader and more ambitious.

Processors have an important role to play in realising the sustainability targets; they can generate the demand by providing incentives for sustainable practices at the primary producers. Additionally, it is important that the focus of the sustainability targets is not only on climate/carbon, but has a holistic sustainability approach. A focus on per kg efficiency gains needs to be adapted to include other key metrics such as total emissions, otherwise it could result in net emission gains due to market share increases.

Significant reduction of GHG emissions can be gained by applying circularity principles for energy (including heat) and water, implementing recent innovations in machinery, adoption of a packaging strategy aimed at minimizing plastic use, whilst maintaining food quality standards. By broadening the business model, for instance including the alternative, plant based, proteins into the portfolio of products, processors not only reduce their own footprint but also contribute to 'normalizing' consuming a plant-based meal.

Policy recommendation

The Irish government can play a key role in maintaining its position as a meat and dairy exporter if it stays on top of new EU regulations and starts implementing these sooner rather than later, in order to give its producers and processors an advantage once the regulations are passed.

Primary producers require targeted support in their interactions with food processors, as they can be highly vulnerable to fluctuations in the market. Yet, providing disincentives, for unsustainable activities will be the next step after the large-scale enrolment in sustainability programs. This will contribute to make the sustainable choice the 'new normal'.

More support is needed for processors to investigate the potential of circular/bioeconomy opportunities in their own organisation and value chain. National and regional authorities play a key role in empowering processors through effective policies to facilitate sustainable circular actions in the long term.

Chapter 6 : A just transition approach

Agriculture is a critical part of the Irish economy, and farming a part of many Irish people's livelihood and cultural identity. However, agriculture is also one of the most unequal sectors in Ireland, with many farmers facing severe poverty. A Just Transition approach provides the foundation and is essential to assure that transformative change occurs in an inclusive and equitable manner; justice will have to become an inherent part of the future economy. There will be no need to emphasize the just transition because it will be understood that the objective of this transition is to achieve greater justice within society, in part through shifting away from ecologically damaging activities such as anthropogenic greenhouse gas emissions.

Policy recommendation

For Ireland to ensure justice within carbon-neutral transition processes, inclusion should be a principle at all levels of policy. This can be done by:

1. including primary producers at the start of the policymaking process so that they feel agency over the process.
2. establishing local task forces across all regions to gather nuanced perspectives and to build region-specific plans for the transition's implementation.
3. organising citizen assemblies, which can provide fora for social dialogue across sections of society whereby consumers and producers exchange and understand each other's position.
4. providing support especially to women farmers who are underrepresented.

To enable this transition and ensure its success, a Food Systems approach is crucial.

All the solutions explored in this report provide different—but overlapping—pieces to the Land-Agri-Food chain transformation puzzle. They may spur trade-offs and require interventions from farm to fork. As such, they are not stand-alone options on a menu to choose from, but need to be designed into a coherent package of interventions that will pave the way towards a net-zero food system by 2050.

A food systems and holistic approach—one that considers all actors, activities, geographies and socio-economic and environmental drivers and outcomes—is therefore crucial to the success of the transformation. Understanding key leverage points, interconnected risks, but also shared agendas and goals can help unlock funding and improve collaboration at the pace and scale required.

Chapter 8: The agri-food funding ecosystem

A systems approach is not a 'nice to have' but a fundamental requirement when funding a transformation of the size of the Irish Land-Agri-Food system. Confidence levels in the ability to actually transition towards a true sustainable and carbon neutral system is still low, delaying the flow of existing, and vast, flows of capital to the regeneration Land-Agri-Food sector. Funding at the pace and scale that is required will continue to fail without a holistic view of the system, with a clear understanding of key leverage points, interconnected risks, and value generation.

Collaborative capital is the way forward, as they enable the provision of funds in key intervention points at the right time, and help minimise the risk for the participants, when adequately structured. Flows of funds are available but allocations in sustainable Land-Agri-Food remain still low. New mission-aligned entrants as well as blended structure participants have an opportunity to accelerate the allocation of strategic funds for the mobilisation of additional private finance towards sustainable Land-Agri-Food.

Adoption of sustainable and/or nature-based inputs is at the core of the transformation. Unlocking the procurement power of large corporations and government in the Land-Agri-Food space will help accelerate the scale of the transformation. True regenerative carbon or nature credits are a promising opportunity to accelerate the mobilisation of funds to heal the land. Real programmes, real work on the ground and verifiable metrics will allow the demand of high-quality claims. This will help companies (carbon buyers) to understand how these investments fit in their commitments – including biodiversity and nature positive commitments, and recognise nature claims as valuable investments that are not meant to be used to compensate for negative impact.

Activating the 'not obvious' leverage points in the Land-Agri-Food space, will allow to re-connect the parts, accelerating execution on the ground, unlocking economic, planet and social value in line with Ireland Land-Agri-Food Vision for 2030.

The Irish government has already embraced systems thinking in its Food Vision 2030. The Deep Demonstration programme will help move beyond 'thinking'—towards the implementation of a carbon neutral Land-Agri-Food system.

EIT Climate-KIC's Deep Demonstration programmes include methodologies and processes to help deliver systemic innovation, which includes working with governments, regions, cities and/or industries to provide support for large-scale transformational change through an integrated, systemic approach to innovation, education and capacity building, entrepreneurship and policy design. The scope is to provide inspirational examples of what is possible, showcasing a resilient future and highlighting the ways that innovation across whole systems can unlock the change we need to achieve a net-zero agri-food system.

The solutions in this report will feed into the development of a portfolio of innovation actions, with sensemaking—a form of fast learning including rapid evaluation and sharing of what works and what does not—at the centre of the process. As a result, connected and supportive decision making and planning is facilitated, which ensures speeding up the transformation.

Introduction

Ireland will become a world leader in Sustainable Food Systems (SFS) over the next decade. This will deliver significant benefits for the Irish agri-food sector itself, for Irish society and the environment. In demonstrating the Irish agri-food sector meets the highest standards of sustainability – economic, environmental, and social – this will also provide the basis for the future competitive advantage of the sector. By adopting an integrated food systems approach, Ireland will seek to become a global leader of innovation for sustainable food and agriculture systems, producing safe, nutritious, and high-value food that tastes great, while protecting and enhancing our natural and cultural resources and contributing to vibrant rural and coastal communities and the national economy.

This is the vision statement made in Food Vision 2030[1]. The National Climate Action plan[2] describes the annual progress and ambitions realising this 2030 vision. The Irish agri-food sector includes primary agriculture, food and drink processing and manufacturing, fisheries, aquaculture and fish processing, forestry and forestry processing and the equine sector. It is Ireland's oldest and largest indigenous industry. In 2020, the sector accounted for almost 7% of modified Gross National Income (GNI*) and 10% of exports in value terms. It employs approximately 164,400 people, representing 7.1% of total employment. At primary production level, some 137,500 farms, over 770,000 hectares of forest, over 2,000 fishing vessels and some 180 aquaculture sites produced an estimated €8.5 billion in output in 2019. The Agri-Food sector produces food and ingredients with a global reputation for quality and safety, with a livestock sector built on an grass-based production system. Realising the ambition as described in the Food Vision 2030 required a systemic transformation of the whole sector. Therefore, the Department of Agriculture Food and Marine of the Irish Government and EIT Climate-KIC started their collaborate in the identification and development of new actions and pathways to help the Food Vision and Climate Action plan to meet their ambitious targets.

EIT Climate-KIC provides systems innovation as a service. and applies the Deep Demonstration as a testbed environment, implementing innovation and learning that can accelerate change, and provide important inputs. The DAFM- EIT Climate KIC partnership is intended to support the ambition of Food Vision 2030 and related policy processes through an approach to agri-food sector transformation that builds a portfolio of strategic, coordinated interventions ('innovations'), testing different levers of change (such as trialling new technology, applying new regulations, developing new markets, incentivising new business models and citizen engagement), which helps the government and sector learn fast about what works best for transforming the agri-food sector in Ireland. This report, dealing with Climate Change and Sustainability targets, intends to feed the portfolio with successful innovations implemented across the globe, and have a potential to contribute to realising a Sustainable Food

1 https://www.gov.ie/en/publication/c73a3-food-vision-2030-a-world-leader-in-sustainable-food-systems/
2 https://www.gov.ie/en/publication/7bd8c-climate-action-plan-2023/#

System in Ireland. Chapters for this report are written by Metabolic, Project X, Circle economy, MTU and EIT Climate KIC. The report has been set up such that each chapter can be read on its own as each chapter describes context, innovations, and recommendations for implementation within the context of the Deep Demonstration. Chapter 9 describes the integral conclusion based on the content of each of the chapters and can be read as the overall summary of the report.

Reading guide

Chapter 1 discusses innovative approaches to deal with climate change. It starts by describing context, trends and Irelands national commitments, policies and strategies. Within the context of the Irish challenges and commitments, Ch 1 provides an overview of measures deployed in practices in agri-food systems across the world and highlights case studies. Finally, recommendations are provided as amidst the challenges of the climate crisis lies a great opportunity to adapt the agrifood sector in Ireland with multiple co-benefits.

Chapter 2 Provides insights in Carbon farming. It describes the concept of carbon farming, gives an overviews of carbon farming options including the mitigation potential, discusses carbon farming as a business model and describes the cost, and funding options for carbon farming. It describes carbon farming in the context of key (EU) policy areas and finally provides recommendations for the development of a carbon market in Ireland, and also showcases the opportunity to go beyond carbon farming and extend the carbon credits with nature credits.

Chapter 3 explores global key themes and trends around alternative proteins that specifically impact the sustainability of the livestock sector from the perspective of feed and examines advantage opportunities for Ireland. After the trends the chapter discusses nutrient sources in animal feed and emphasises the potential for aquafeed. The opportunities that alternative proteins provide for human diets are explored. The chapter finally offers some Ireland specific views on innovation potential in alternative proteins and proposes a set of recommendations.

Chapter 4 takes an international perspective to the circular economy approach, presenting insights that could aid Ireland's agrifood sector in transitioning to a more sustainable system. The chapter starts by introducing the concept of a circular economy in the context of agrifood systems, identifying three key pillars of circular food systems. The 3 pillars; i) Regenerative and, where appropriate, local food production; ii) low-impact and healthy diets and iii) designing waste out of food and food packaging are further elaborated in the following sections. by first identifying international best practices, then common barriers and, finally, relevant policy recommendations to overcome them, at both national and local levels. These insights are integrated to provide and international perspective to analyse the Irish agrifood system going forward. Finally, the chapter provides key recommendations for Ireland going forward, to fully embrace the concept of circular economy in its effort to create a truly sustainable and regenerative agrifood system.

Chapter 5 starts by describing the current state of sustainability in the chain, describes the European developments in the meat and dairy sector and highlights sustainability leaders in the meat and dairy sector. Next circular and carbon neutral innovations in the chain are described and the chapter ends with recommendations for the Irish government.

Chapter 6 describes the frameworks and principles of a just transition. Analyses the trends present in the Irish agrifood sector, assessing the challenges and identifying the opportunities that can be drawn from them. Best practice case studies are included as inspiration for how justice in transition is being pursued in similar sectors around the world. Finally, recommendations are given for policy makers in Ireland to set their sights upon as they pursue the governance of a Just Transition for the Irish Agrifood sector.

Chapter 7 offers an in-depth Irish focussed approach to circularity and the bioeconomy, providing an overview of the current landscape, recent developments and future sustainable pathways. Topic areas include the reduction of food waste across the value chain, innovation in sustainable biobased packaging solutions, circular business models for industry growth and the creation of connections between the quintuple helix of stakeholders; environment, civic society, government, industry and academia.

Chapter 8 aims to highlight a key intervention points and the relevant leverage points required to accelerate the mobilisation of funds to transform the agri-food sector in Ireland. It highlights key aspects to achieve a multiplicity of changes, at the scale and pace that is needed. The chapter is developed using system logic and considers several elements that are relevant to the mobilisation of funds to the global agri-food sector. These include, in addition to relevant funding instruments and blended finance mechanisms, emerging trends, collaborative approaches and the 4 order challenges.

Chapter 9 provides the integral conclusion of the report.

1. Dealing with climate change

Authors:
Anne de Valença | Elise Eijs
Alexandra Fox | Willow Sommer

Credit: Shuttershock

Acknowledgements

Metabolic would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Authors: Metabolic: Anne de Valença, Elise Eijs, Alexandra Fox, Willow Sommer

Reviewers

Saskia Visser (EIT Climate KIC), Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC)

How to cite this Chapter:

Metabolic. (2023). Dealing with climate change. Chapter 1 in: Dealing with climate change and sustainability targets: The innovation potential for the Irish agri-food sector

Dealing with climate change

Food production systems inherently rely on their natural environment and climatic conditions. Droughts and other extreme weather events are likely to become more common as global temperatures rise and disrupt the natural balance that humans have relied on for thousands of years. In Ireland, primary producers are already experiencing these changes, as the 2019 potato harvesting difficulties and 2018 fodder shortages illustrate. Agriculture plays a significant role in the Irish economy, especially since the exponential growth in exports of food and beverages in the last decade. Climate change is now putting this sector at risk and for it to sustain, adaptation is necessary.

Importantly however, food systems are also major contributors to global emissions, and are responsible for a quarter of the world's greenhouse gas (GHG) emissions. In Ireland, agriculture alone produces 37.5% of the nation's total GHG emissions. This is significantly higher than other EU countries where the average contribution of agriculture to total GHG emissions is 10% (Verschuuren, 2022). On top of that, the Irish agrifood sector is also a major polluter of air and water systems, threatening human health and ecosystem integrity. If the agrifood sector continues to produce food in such an unsustainable manner, it risks undermining the resource base it depends on.

The Irish food system has a vital role to play in climate mitigation, but also in the improvement of air and water quality. Fortunately, actions that can cut emissions can also gain multiple positive co-benefits in terms of water and air quality but also for soil health, green job creation, public health benefits, reduced vulnerabilities, and improvement of biodiversity. Interventions to improve nutrient management, for instance, can not only reduce CO_2 and N_2O emissions but also enhance water, air and soil quality, and improve crop productivity and biodiversity.

The current and projected climate change impacts stress the urgent need for major developments and advances in climate adaptation and mitigation action, and for ambitious policies to help implement these actions. Ireland acknowledges its part in contributing to EU and global climate efforts and has set up robust climate policies such as the agrifood Sector 2030 Vision. One of Ireland's most significant targets is a 51% greenhouse gas emissions reduction by 2030 (Government of Ireland, 2021). Of this, 25% of the emission reductions should be achieved within the agricultural sector. This step-up can help Ireland achieve a climate-neutral economy and climate-resilient society by 2050. The objective is clear, but the path forward is being negotiated by the stakeholders involved.

Seeing as climate, air and water issues are interconnected, this chapter will research measures to address these challenges simultaneously. Thus, the objective of this chapter is to understand what measures contribute to climate mitigation, air quality and water quality, and may be relevant for the Irish agrifood sector.

1.1 Context & Trends

Irish agrifood sector

The agrifood sector is a major economic sector, employing 7% of the workforce and contributing over 6% of GNI (DAFM, 2022). The industry has expanded rapidly since 2010, due largely to a strong focus on food and drink exports. Agrifood exports reached a record of €14.2 billion in 2021, the majority of which (€5 billion) is accounted for by dairy (DAFM, 2022). This dairy sector growth can be attributed in large part to the removal of the EU milk quota in 2015. The abolition of those production restrictions to prevent surplus volumes initiated a major dairy expansion and productivity growth, leading to increased GHG emissions (Fitzgerald, 2019; Läpple et al., 2021). The industry continues to expand and export values are expected to grow towards €19 billion by 2025 (DAFM, 2015). Dairy and arable farming are the most profitable sectors, with gross outputs of €4,324 and €2,218 ha/year respectively, and family farm incomes of €1,548 and €839 ha/year respectively (Buckley & Donnellan, 2022).

Livestock is the largest agricultural sector, both in terms of economic value and land use. The sector covers 4.1 million ha - 60% of total land surface and around 90% of agricultural land - and is dominated by pasture based dairy, beef and sheep farming. Primary production of livestock commodities is valued at over €7 billion, of which the dairy and beef sectors contribute almost 70%.

Arable farming covers 300,000 ha - around 9% of agricultural land (Wallace, 2020) - and is dominated by cereal production, particularly wheat, barley and oats; although other crops such as oil rapeseed and pulses are also upcoming. The industry is considered the second most viable, behind dairy farming, with average annual family farm incomes of €98K (Dillon et al, 2021). As 75% of the cereal production is used as animal feed, the land footprint of the livestock sector actually adds up to almost all agricultural land (DAFM, 2015).

Other dominant types of land-use are forestry and peatland extraction. Forestry covers nearly 800,000 ha hectares (11% of the land surface) and supports an export-oriented forest products sector worth €2.3 billion annually (DAFM, 2022). Nearly 700,000 ha of peatland have been subject to turf cutting or industrial purposes as these resources provide much demanded growing material for horticulture or home gardening and 14% of household electricity production (National Parks & Wildlife Service, 2014). However, in recognition of the impacts of peat extraction and burning on CO_2 emissions and air quality, the Irish High Court issued a ban for large-scale turf cutting and sale in 2019.

Climate change

Ireland is far from reaching its climate targets of halving emissions by 2030 and reaching net zero by 2050. Although GHG emissions have been decreasing since 2005, the overall emissions have increased by 11.4% since 1990. Agriculture is consistently Ireland's largest GHG emitting sector, contributing 37.5% of all emissions (Figure 1) - which is a relatively large contribution compared to other countries

(Mielcarek-Bocheńska & Rzeźnik, 2021). In comparison, the transport and energy sector contribute 17.7% and 16.7% respectively. GHG emissions from the Irish agricultural sector increased by about 9% over 2005-2020, and are projected to continue rising with the measures currently in place.

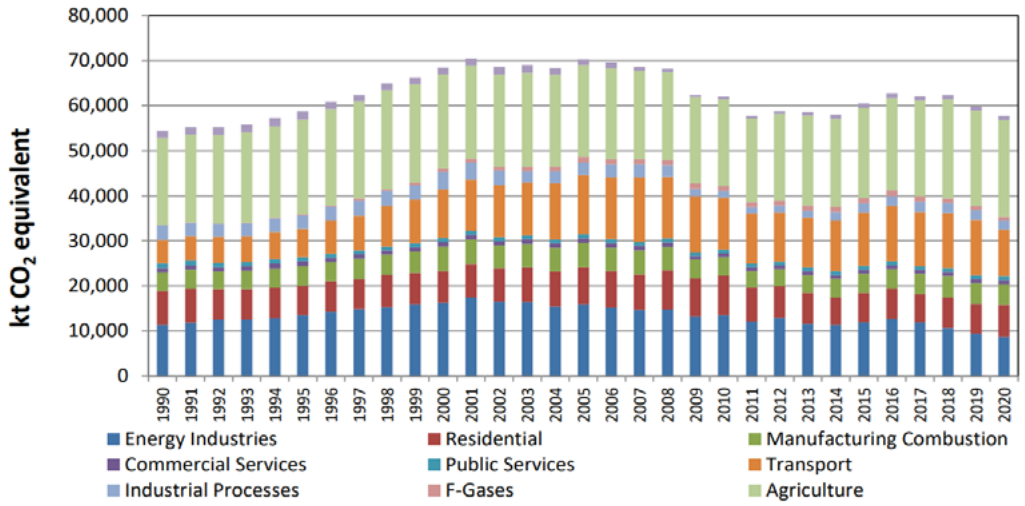


Figure 1.1: *Greenhouse gas emission trends (CO_2-eq) from various sectors in Ireland from 1990-2020. Agriculture is the largest contributing sector (37%), and total emissions have increased since 1990 (11%). Source: Climate Action Plan 2021.*

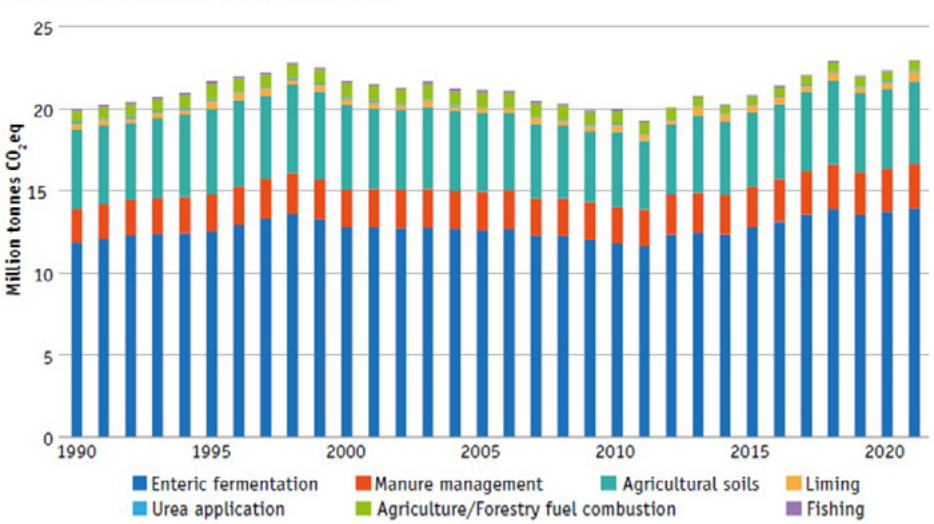
GHG emissions from the agricultural sector mainly come from livestock enteric fermentation (methane, CH_4), agricultural soil management (carbon dioxide, CO_2, nitrous oxide, N_2O) and manure management (CH_4 and N_2O) (Table 2). Enteric fermentation from livestock is the most prominent GHG emitter in the agricultural sector, with dairy farms showing the highest emissions per hectare. In 2021, average dairy farms emitted 614 tonnes CO_2-eq (9.5 tonnes/ha) compared to 157 tonnes CO_2-eq (4.7 tonnes/ha) for cattle farms, and lower for sheep farms (Buckley & Donnellan, 2022).

The high emissions can be attributed to the greater production intensity on dairy farms - including higher stocking rates, more energy intensive diets and higher use of fertilizers. Arable farming has a much lower carbon footprint than livestock systems, although the emission amounts are highly dependent on the farm types, especially cropping intensity. The average arable farm emitted 176.9 tonnes CO_2-eq in 2021 (2.5 tonnes/ha). However, only 32% of these emissions were generated from crop production. The remainder of emissions can be attributed to cattle or sheep present on arable farms.

Land use, land use change and forestry (LULUCF) is a major source of CO_2 emissions. Ireland has a significant number of grasslands, mineral soils and peat, and forests which sequester carbon dioxide. Yet the conversion of these natural carbon sinks can turn them into carbon emitters, thus reversing the potential they have for climate change mitigation. Peatlands account for approximately 53% of Ireland's soil carbon stock, storing an estimated 1.5 billion tonnes of carbon, despite only representing 17% of the land area (Tomlinson, 2005 ; Renou-Wilson, 2011). Drainage and peat cutting has led to a 47% loss of peatland habitats. In addition, conversion to forest, overgrazing and agricultural reclamation have also led to peatland losses of 19%, 5% and 6%, respectively, as well as soil degradation, changed hydrol-

ogy and nutrient status and major loss of peatland biodiversity. Drained peatlands and related activities have been reported to emit around 11 million tonnes CO_2/year, which is equivalent to the emissions from the energy sector in 2018 (Duffy et al, 2018; Renou-Wilson, 2011). The forestry sector on the other hand is currently a net carbon sink, due to the afforestation efforts which need to be maintained for the next 20 years. However, the negative impact of peatland drainage outweighs the positive impact of forests, making LULUCF a net emitter of GHG emissions.

Figure 1.2: *Agriculture trend in* CO_2 *emissions (million tonnes* CO_2*-eq) between 1990-2021. Source: Ireland's Provisional Greenhouse Gas Emissions Report 2022*



The impacts of climate change are emerging across Ireland. Overall, the country is getting warmer and wetter. The annual mean temperature has already increased by 0.9 °C since 1900, and this continued trend is heading towards a 2 °C increase by the early second half of this century (García & Dwyer, 2020). In addition, rainfall in winter has increased, while decreasing in summer and spring. These trends all impact agriculture in the growing seasons. Extreme weather events are expected to occur more frequently, with widespread effects. Heat waves will impact human health as well as phenological phases in many plant and animal species. More frequent dry periods and heavy rainfall will increase both droughts and flood risks. Rising sea temperatures and sea levels and ocean acidification will have serious effects on marine and coastal ecosystems and on the communities depending on them.

It is clear that climate change presents a real and actual challenge for Irish agriculture. The predicted impacts of climate change will vary spatially and between farming systems (Hennessy, 2010) and will mostly relate to pests and diseases, crop yields, flooding, plant and animal stress factors. In arable systems, the yield of crops that are dependent on tillage such as potatoes and cereals are likely most exposed to drought. Pasture-based livestock systems can be negatively impacted when heat stress affects animal health, or when irrigation is needed in dry periods while water supply competition is growing, and grazing on wet soils after heavy rainfall is not always realizable (Royal Irish Academy, n.d.).

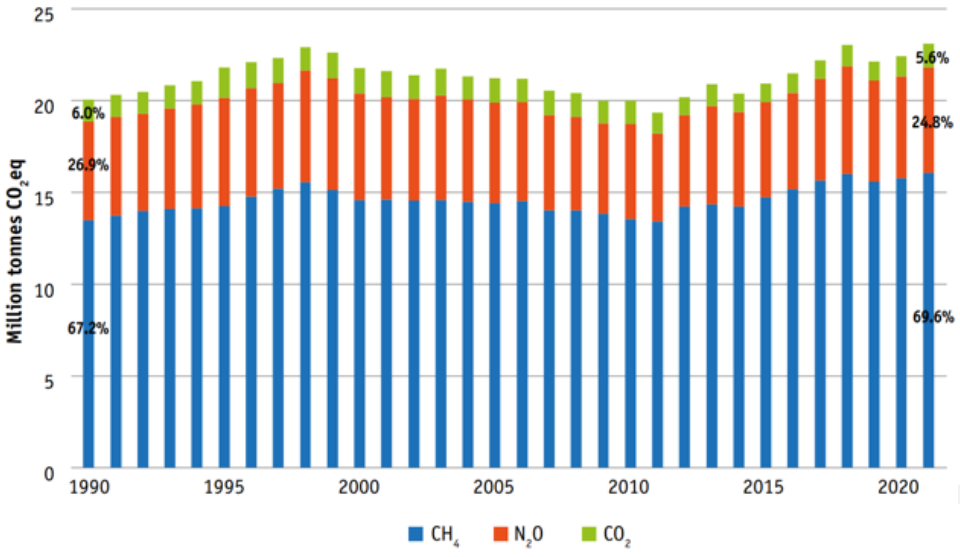
It is expected that climate change impacts will cost the country €1-2 billion/year by mid-century (Flood, 2013). This highlights the importance of adapting existing agricultural systems and practices to help mitigate and control these climate impacts.

Air quality

In 2020 poor air quality caused approximately 311,000 premature deaths in Europe (EEA, 2022). Although Ireland's air quality is better than many of its European neighbours, the death toll here lies at 1,380 people per year, which is still a significant number of avoidable deaths. In addition, the majority of air stations do not satisfy the more stringent WHO Air Quality guidelines, which are standards that Ireland and Europe want to move towards.

Air quality is strongly related to climate change. Climate change happens as a result of increased levels of greenhouse gasses in the air, in particular CO_2, CH_4, N_2O (Figure 3) and indirectly NOx (leads to the formation of ozone, an important greenhouse gas). NOx is toxic even at relatively low concentrations (Mukherjee & Agrawal, 2017) but CO_2, CH_4, N_2O are not normally considered air pollutants, as they occur naturally in the air. However, the significant increase in these three gasses following human activity has been linked to harmful air pollution. The global warming effect increases temperatures and humidity locally, which can enhance smog formation, adversely impacting human respiratory health. In addition, emission of these greenhouse gasses is associated with livestock rearing, which usually happens in combination with air pollutants such as NOx and NH3 (and consequently Particulate Matter (PM).

Figure 1.3: *Greenhouse gas emissions per gas* CO_2, CH_4, N_2O *(million tonnes* CO_2*-eq). Source: Ireland's Provisional Greenhouse Gas Emissions Report 2022*



Nitrogen oxides (NOx), ammonia (NH3) and particulate matter (PM) are direct air pollutants. NOx is a collective term referring to two gasses: nitrogen monoxide (NO) and nitrogen dioxide (NO2). These gasses have natural sources (lightning, forest fires) and non-natural (agricultural fertilization, combus-

tion from transportation, industry). Although the naturally produced nitrogen oxides massively outweigh the man-made emissions, the latter are found at altitudes lower than 5km, particularly near the sources, which can lead to significant human health effects. E.g. increased inflammation of the airways; reduced lung function and increased likelihood of general respiratory problems. NH3 can indirectly contribute to GHG emissions but is not directly harmful to human health. It stays in the air only a few hours after being emitted, and can mix with other gasses in the atmosphere such as NOx and S2O. This can produce particulate matter (PM), which can exist for several days and travel long distances (Baek & Aneja, 2005). The toxicity of PM is mainly related to particles with a diameter of less than 10µm, whereas PM10 includes particles less than 10 µm in diameter and PM2. 5 those less than 2.5 µm. High concentrations of PM10 and PM2.5 are linked to major human health issues. As NH3 is an important precursor of PM, it plays an important role in air quality and human health. Almost all ammonia emissions (99%) in Ireland come from agriculture via the spreading of manures and slurries (75%) and synthetic NH3-based fertilizers (25%). Reducing the emission of these gasses is therefore a key intervention area for both climate change and air quality affecting human health.

Water quality

Water pollution is a serious problem in Ireland, and addressing the issue is important for both climate and biodiversity goals. Water ecological health is not satisfactory in 50% of Irelands' rivers, 31% of lakes, 64% of estuaries, and 19% of coastal waters. Even though improvement targets have been set, water quality has been steadily declining since 2016. The majority of groundwater bodies (91%) are in satisfactory condition, but some in the south and southeast have elevated nitrate concentrations which poses a serious threat to human health. Poor water quality does not only increase biodiversity loss and threaten human health, but also causes higher GHG emissions (Ho et al, 2020). Water pollution and eutrophication affect microbial communities and underwater soils, which are part of the carbon cycle, causing them to emit more greenhouse gasses than in healthy waters.

Agriculture is the main cause of water pollution in Ireland. The run-off of nitrogen and phosphate from agricultural land causes nutrient pollution, which affects about 30% of rivers and lakes and about 25% of estuaries. Such high concentrations of nutrients in natural water bodies is called eutrophication and causes excessive plant and algal growth (algal bloom). The processes affect fish and other water organisms, with devastating effects for both biodiversity and GHG emissions. Especially intensive livestock farming is responsible for these detrimental impacts, and the increased herd sizes and fertilizer use over the last decade has led to increasing nitrogen levels in the water.

If current water quality declines continue, it is unlikely that the targets set in Ireland's second-cycle River Basin Management Plan will be met. Nearly 1,500 water bodies have been identified as being at risk of not meeting their environmental objectives. Climate change increases the pressure on water bodies, e.g. through more frequent storms and heavier rainfall or drought. Waters which are clean,

ecologically healthy and relatively free of pollution are more resilient to the effects of climate change. Changes in agricultural practices can therefore also positively impact water quality in Ireland and consequently improve human and ecosystem health, plus contribute to climate change mitigation.

1.2 Ireland's national commitments, policies and strategies

The Irish government is conscious of the need for change in the agrifood sector and has acted by putting ambitious policies in place. This section summarizes those policies to provide a context for further recommendations.

Climate

The Climate Action Plan 2021 (updated annually) sets out a roadmap to reduce overall greenhouse gas emissions by 2030 by 51% against 2018 levels and to become a climate neutral economy no later than 2050. To support this commitment, the Climate Action and Low Carbon Development Act of 2015 was amended and strengthened in 2021, legally binding Ireland to achieve the 2030 and 2050 targets. Of these reductions, 25% should be achieved through the agricultural sector, since the government recognises the immense emissions coming from this sector. These targets are in line with the Paris Agreement goals and are further guided by the EU Climate and Energy Framework, the new European Green Deal agenda, including the Farm to Fork strategy and Biodiversity strategy, and the Common Agricultural Policy (CAP). One policy document that is instrumental in reaching these targets is Ag Climatise (2020), a roadmap published by Ireland's Department of Agriculture, Food and the Marine (DAFM) in 2021. In its vision, Ag Climatise highlights the need to reduce GHG emissions, especially biogenic methane, and to meet ammonia reduction targets, increase carbon sequestration through land use, reduce nutrient loss and improve water quality and biodiversity, and build sustainable, resilient food production systems. The Food Vision 2030 for Ireland's agrifood sector uses a more holistic view of agrifood and employs a food systems approach to propose solutions, adding a more transformative view to changing the food system. No matter how successful climate mitigation efforts prove to be, Ireland's society will still feel the impact of past emissions. Thus, the Government has also set up the National Adaptation Framework (NAF) and its constituent sectoral plans to prepare for these challenges.

Air

To mitigate the impacts of air pollution on people's health, Ireland follows the EU National Emission Ceilings Directive, which establishes limits for five air pollutants: ammonia (NH3), nitrogen oxides (NOx) and fine particulate matter (PM), as well as non-methane volatile organic compounds, sulfur dioxide. If Ireland implements the planned policies and reduction measures as outlined in Climate Action Plan and Ag Climatise, GHG emissions as well as air pollutants can be significantly reduced. Especially ammonia emissions have been at concerning levels for the past few years and compliance with the regulations will be necessary to meet the EU legal air quality standards. In addition, Ireland can meet the

more stringent WHO guidelines if it acts according to its climate goals. To further guide this transition to better air quality, the Clean Air Strategy is being drafted and builds upon the 1990-2030 National Air Pollution Control Programme (NAPCP).

Water

The EU Water Framework Directive guides all water policy and management in Ireland, which means the country must meet the target of achieving at least "good status" for all water bodies by 2027. Several initiatives, including second-cycle River Basin Management Plan 2018-2021, have made progress towards this goal, but many water bodies are still seeing a decline in quality, mostly due to agriculture. The next cycle of the River Basin Management Plan will need to take more concrete measures. In addition, the Government has recently published Ireland's Fifth Nitrates Action Programme which sets out new measures to prevent pollution from nutrient and sediment losses from agricultural sources and to protect and improve water quality (Fifth Nitrates Action Programme, 2022). These are mostly targeted at the livestock sector, as it is the main sector contributing to water pollution.

Concluding remark

The links between climate mitigation and adaptation, air quality and water quality plans and programmes need to be further developed to ensure they can achieve multiple benefits for as many target areas as possible. Therefore, in the next section we will attempt to explore some innovative approaches to climate mitigation in the Irish agrifood sector, some of which have been suggested by the government itself, while others are less well established despite their high potential.

1.3 Evaluation of climate mitigation measures

The Irish agrifood sector remains the largest contributing sector to the country's GHG emissions, with 37% of the total emissions. As Ireland aims to achieve a climate neutral economy by 2050, there is an urgent need to identify and implement climate mitigation measures for the Irish agrifood sector.

Climate mitigation measures are actions which lead to lower emissions of greenhouse gasses, compared to the status quo. Climate mitigation measures often have co-benefits and/or trade-offs regarding water quality and air quality, as well as climate adaptation and agricultural productivity.

In this section, we highlight climate mitigation measures deployed in agrifood systems around the world. Next, we discuss several measures which seem most relevant to the Irish agrifood sector. Per measure, it is discussed how they can be deployed, generate co-benefits and trade-offs and what examples already exist to take inspiration from.

Credit: shutterstock

Measures deployed in practice in agrifood systems around the world

When selecting relevant and effective climate mitigation measures for the Irish agrifood sector, it is useful to analyze what is being done in other global regions to address this issue. Comparisons should take into account that agrifood systems and climate change issues are highly context-dependent and thus measures should be selected using a tailored approach.

Nevertheless, there are several key climate mitigation measure domains applicable to all global regions which can be prioritized for action. The 2020 IPCC report dedicated a Special Report on climate change related to land use and listed the following domains for high-potential climate mitigation interventions (Figure 4):

- Improved agricultural land management, especially agroforestry, improved management of crop-land, livestock, and grazing land.
- Improved forest management and reduced deforestation and forest degradation.
- Improved soil management, especially increased soil organic carbon content.
- Improved management of other ecosystems, especially fire management, and restoration & reduced conversion of peatlands and coastal wetlands.
- Improved value chain management, especially the demand-side including reduced post-harvest losses, dietary change, and reduced food waste (consumer or retailer).

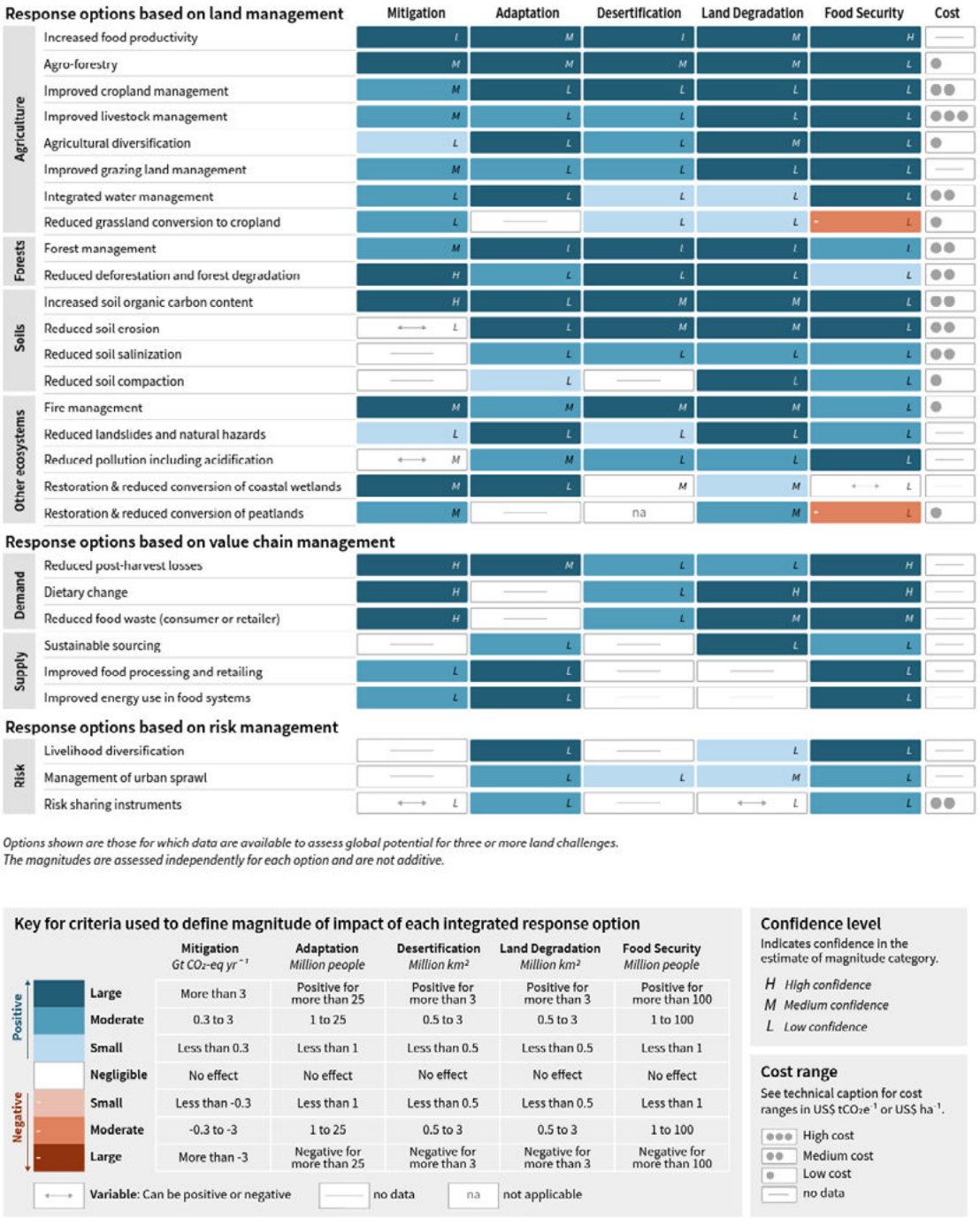


Figure 1.4: *Potential global contribution of response options to climate mitigation and co-benefits. Source: IPCC, 2020.*

Within the EU, climate mitigation measures are supported through the EU policies and regulations such as the Common Agricultural Policy (CAP), Nitrates Directive and LULUCF Regulation/Decision. Measures most widely adopted in EU-27 national policies and implementation programs are listed in Table 1, along with gaps in reported measures (German et al., 2021).

Table 1: *Overview of existing agricultural climate mitigation measures and gaps in EU27 national agricultural policies and measures. Adapted from German et al, 2021. Underlying sources: Perez-Dominguez et al, (2016), Ricardo-AEA (2016) and ECA (2021).*

Focus area	Most frequently-reported measures	Gaps in reported measures
Livestock	Optimizing livestock diets, breeding, health and disease management; improving manure management systems; and promoting anaerobic digestion 'biogas'.	Reducing livestock numbers is still uncommon. Supporting targeted breeding and using feed additives to reduce enteric methane emissions are rare, and these measures are mostly yet to be implemented.
Reduction in crop and soil N_2O	Reducing the quantity of nitrogen applied to soils, using low emission-spreading equipment, supporting organic farming and introducing organic fertilizers.	Support for nitrification or urease inhibitors is rare, despite their potential efficacy. Precision farming allowing more effective use of inputs (e.g. variable-rate nitrogen technology, pesticide application and precision irrigation) is also lacking.
Carbon storage/ sequestration	Maintaining or enhancing woody biomass on farmland (e.g. through agroforestry), implementing grassland management to enhance soil carbon stocks, using cover crops and conserving organic soils.	Explicit support for permanent conversion of arable land to grassland or wetland, including ponds where appropriate, is lacking. This would limit drainage and restore carbon-rich ecosystems, and incentivise sustainable soil management.
Energy mitigation	Improving on-farm energy efficiency, excluding measures relating to biogas (this is covered as a manure management measure).	Carbon-auditing tools are not frequently mentioned, despite their high mitigation potential.
Wider food system	Awareness-raising and education among consumers, food labeling and repealing the waste status of by-products to allow use/reuse as a resource were measures proposed to encourage dietary shifts and reductions in food waste. Some Member States included plans to reduce reliance on imports by increasing domestic food and animal feed production.	Relatively few countries reported measures to encourage dietary change, shortening supply chains or reductions in food waste (e.g. through improvements in food redistribution systems, financial mechanisms supporting reductions in food waste, registration and monitoring of procedures).

Selected climate mitigation measures for Irish agrifood sector

To select those climate mitigation measures which are most relevant for the Irish agrifood sector, we analyzed the sector's main challenges and the measures that are already in place. In Ag Climatise (2020), DAFM has presented a roadmap with 29 actions in the agrifood sector to reduce GHG emissions. Considering this list of actions, and taking a food systems approach by considering the most impactful and feasible measures including their co-benefits and trade-offs (Kennedy et al, 2021; German et al, 2021), we selected 6 climate mitigation measures for the Irish agrifood sector to meet the climate goals (Table 2). Not all measures are included in Ag Climatise, which suggests the gaps highlighted in Table 1 are also present in Ireland.

The six measures (Table 1) were selected using a food systems approach, which involves a reconsideration of what is produced and why. Rather than tweaking current production systems to achieve mild emissions and pollution reductions, production systems should be redesigned to provide food within the carrying capacity of Ireland's ecosystems. This means: taking the healthy local ecosystem as the baseline and operating without exceeding any boundaries affecting that healthy space. Alongside the neutral or preferably positive impact on ecosystems, the food systems approach considers an inclusive value chain providing food and income security and equity. The package of the six selected measures implies a rather substantial and challenging agrifood system transformation, but does ensure emission efficiencies are effective contributions to long-term sustainability in Ireland.

Most of the selected measures are Nature-based Solutions (NbS). NbS are powerful approaches which not only provide climate mitigation and adaptation benefits, but also increase biodiversity, strengthen ecosystem services, including food, health and water security, and help sustain and support livelihoods (Cohen-Sacham et al, 2016; Nesshover et al, 2017). The solutions rely on natural systems rather than technological solutions. It is estimated that NbS can deliver up to one-third of the global net emission reductions required by 2030, through restoration and avoidance efforts of: peatland restoration, cover crops, trees in croplands and coastal restoration, and avoiding deforestation, peatland impact and coastal impact (World Economic Forum, 2021). These natural solutions already exist and require minimal investment in innovation - just smart implementation.

An example of a successful Nature-based Solution in Ireland is peatland restoration. The Ireland Recovery and Resilience Plan (corona recovery fund) invested €108 million to restore 33,000 ha of damaged peatland with the intention to dramatically reduce carbon emissions, improve air quality and water quality - thereby reducing threats of floods and fires - and support biodiversity. On top of the public investments, restoration efforts can be profitable for landowners through carbon credit markets, such as MoorFutures in Germany which supported the livelihoods change of turf-cutters.

Credit: Shutterstock.

Another consideration for selecting effective climate mitigation measures was the focus on net reduction in agricultural GHG emissions. When this is not explicitly stated as a goal, interventions that produce lower emission intensity per product are often selected and implemented. These efforts can produce a rebound effect, whereby production volume increases result in flat overall emission trends, which has been seen across EU-27 (German et al, 2021). Since 2000, net agricultural GHG emissions have not decreased, despite implementation of effective climate mitigation measures. A similar situation can be found in Ireland, where the livestock sector has grown substantially, and consequently, GHG emissions of the agrifood sector increased despite the relatively low emission intensity per livestock product (Figure 5; German et al, 2021). Hence, it is important to not only focus on low-emission measures, but also to transform e.g. food and feed demand to reduce total sector emissions.

Table 2: *Six selected climate mitigation measures for the Irish agrifood sector to meet the climate goals. Adapted from Lankoski et al, 2018.*

Measure	Co-benefits and Trade-offs				
	Mitigation	Adaptation	Water quality	Air quality	Productivity
Extensive ruminant farming (with reduced herd size)	High mitigation potential because of reduced livestock numbers, reduced feed and fertilizers use, and improved soil quality	Better resilience due to improved animal and soil health (e.g. soil water holding capacity); less dependency on external feed availability	Better water quality due to lower synthetic nitrogen fertilizer application and leaching	Better local air quality around livestock farms due to reduced emissions of nitrogen oxides (NOx) and ammonia (NH3)	Potential increases per Livestock Unit due to health benefits, but total production may decline in the short term
Methane- reducing feed additives for ruminants	High mitigation potential because feed additives can reduce methane emissions from enteric fermentation	Slightly increased climate resilience due to improved animal health and diversified sources of feed	No direct link with freshwater quality; Potential better water quality in coastal waters where through reduced eutrophication	No direct link with air quality	Potentially higher yields per Livestock Unit due to improved diets
Nitrogen from crop diversification and N-fixing plants	High mitigation potential, particularly crop rotation with legumes, due to reduction in synthetic N use and improved soil carbon storage potential	Improved soil fertility and water holding capacity increases resilience to climate change	Better water quality due to lower synthetic nitrogen fertilizer leaching to local water bodies	Better air quality, due to decreased release of NOx from soils	Increased soil fertility and yields over the medium to long term due to nitrogen fixing in soils; Short-term losses due to reduced cropping intensity
Agroforestry	High mitigation potential through increased soil carbon sequestration by trees and shrubs	Increased resilience to climate change due to improved soil conditions and water management; Benefits in terms of livelihood diversification	Potential positive impact wwhen agroforestry design prevents nutrient runoff (e.g. hedgerows) and less synthetic N fertilizers are applied (less needed in diverse agroforestry systems)	Improved air quality due to gaseous pollutants such as ozone, CO, NO2, SO2 which are absorbed and broken down in trees. PM removal from atmosphere through deposition on leaves	Potential improved yield adjacent to cropland due to better rainwater management and reduced erosion; Potential reduced yield through competition for light, water, nutrients
Paludiculture	High mitigation potential through reduced emissions and increased carbon sink of peat soils	Increased resilience due to a stabilized water table and higher water retention	Improved water quality, through e.g. purifying effect of peatland plants and reduced mobility of pollutants	Improved air quality through reduced household peat burning and reduces peatland fire risks	In general biomass production decreases, but productivity changes differ across paludiculture systems
Plant-based production systems	High mitigation potential due to lower carbon footprint compared to animal systems	Increased resilience due to improved soil health, and diverse income sources	Potential to improve water quality by reducing reliance on nitrogen fertilizers.	Improved local air quality due to reduced ammonia emissions	Productivity rates cannot be compared directly as the products differ

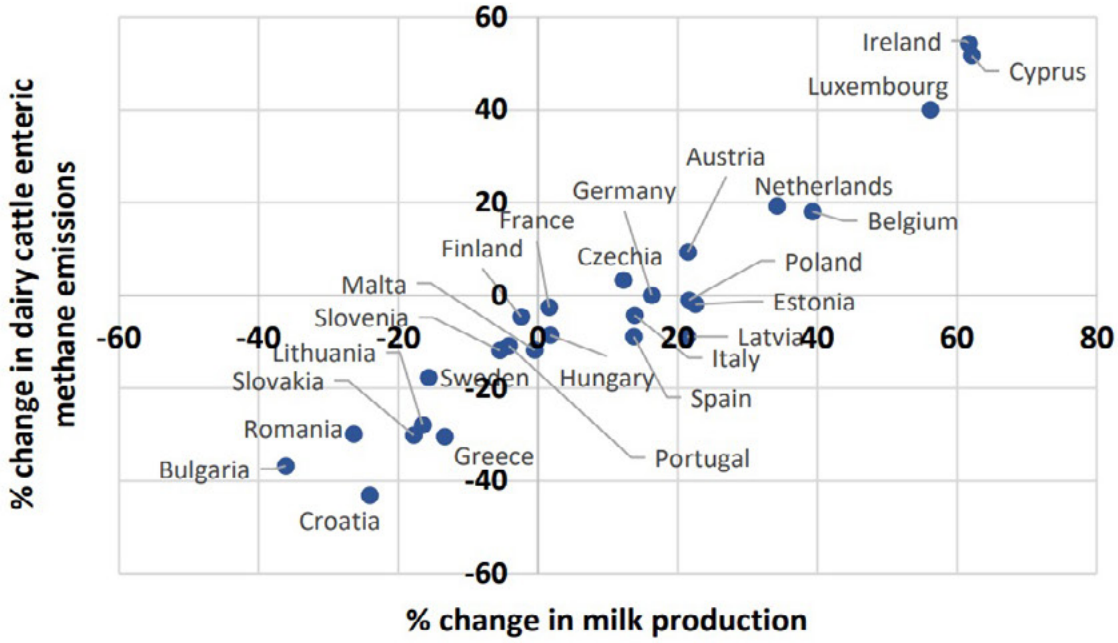


Figure 1.5: *Scatterplot showing percentage change in dairy cattle enteric methane emissions against change in milk production by MS, between 2005 and 2019. Source: German et al., 2021.*

The main source of the Irish agrifood sector's GHG emissions are livestock - particularly from enteric fermentation and manure management - and synthetic nitrogen fertilizers. Measures to address the livestock sector's emissions include 1) Extensive ruminant farming (with reduced herd size) and 2) Methane-reducing feed additives for ruminants to decrease the emission intensity per hectare and per animal, alongside a shift to 3) Plant-based production systems and diets. Measures to address emissions from synthetic nitrogen fertilizers are summarized as 4) Nitrogen from crop system diversification and N-fixing plants, which also includes crop rotation and cover crops. Furthermore, 5) Agroforestry production systems are selected as they have major potential for carbon sequestration, which is needed to compensate for unavoidable GHG emissions from the agrifood system. The same accounts for measure 6) Paludiculture, which includes a range of production systems on rewetted peat soils to stop emissions from drained peatlands in Ireland and transform the soils back into carbon sinks. Each measure is discussed in the sub-sections below regarding: what it is, climate mitigation potential, co-benefits, trade-offs and case studies.

Extensive ruminant farming (with reduced herd size)

The livestock sector is the largest contributor of GHG emissions in the Irish agrifood sector, contributing to about 80% of GHG emissions which are related directly to the number of animals and the management of the manure they produce - mostly dairy and beef (Ag Climatise, 2020). Therefore, it is critical to reduce the sector's net emissions. Rather than emission reductions per product, emission reductions per hectare are a key leverage point to prevent perverse incentives for increasing production (and the associated risk to outbalance efficiency gains).

Extensive livestock farming, particularly dairy and beef, can be a very effective measure to reduce GHG emissions per ha from the livestock sector (Casasús et al., 2012). Extensive livestock farming implies low input production systems, which are in balance with ecological thresholds of the agro-ecosystem. In the context of dairy and beef in Ireland, it implies pasture-based systems where ruminants are mostly grass-fed (minimal input of protein feed) using rotational grazing approaches, and where grasslands are managed naturally (minimal input of synthetic fertilizers and other agrochemicals). The amount of ruminants that can be fed per ha of natural grassland is limited and varies across fields ("carrying capacity"), but generally implies a lower amount of animals per ha compared to current conventional ruminant systems. Thus, a general consequence of extensive dairy and beef farming is a reduced herd size per hectare. This leads to reduced net GHG emissions from the livestock sector, assuming area of land does not increase.

The climate mitigation potential of dairy and beef is respectively 2.8 t CO_2-eq and 1.1 t CO_2-eq per destocked ruminant per year. The livestock sector could decrease emissions by 2030 with 30% when reduced herd sizes of 18% for dairy and 22% for beef (i.e. from 12.4 million ruminants to 10.6 million ruminants) plus 5% less pigs, poultry and sheep, plus multiple soil & fertilization measures (KPMG 2021, scenario 3). With even larger herd size cuts of 45% dairy and 47% beef, emissions reductions can go up to 50% (scenario 4). Adding to this, climate benefits of extensive dairy and beef farming come from the reduced use of supplemental animal feed and synthetic nitrogen fertilizers, which have a carbon footprint at the production, transport and application processes. Moreover, improved grassland soil quality will add to the mitigation potential as it functions as a carbon sink.

Co-benefits of extensive animal farming are major. Improved soil and animal health increase the climate change resilience (Villalba, 2016; Bogunovic et al, 2022). Extensive grasslands have more natural vegetation and improved soil water holding capacity, which enhances resilience during droughts as well as heavy rainfall periods - which will occur more often with climate change. Grass-fed livestock systems also reduce demand for animal feed production, which should increase land availability for e.g. crop production (incl. plant-based proteins), agroforestry and nature. Water quality is positively affected by extensification, as the reduction of synthetic N fertilization of grasslands mitigates N leaching into local water bodies, improving water quality. Air quality can be improved in areas with problematic amounts of ammonia emissions (Grinsven et al, 2015). Reduced ammonia emissions also have a positive impact on biodiversity through avoided nutrient loading in local ecosystems.

The main trade-off of livestock extensification, productivity loss, has been and continues to be the main roadblock for this measure. Extensification leads to lower productivity per animal as well as lower production volumes per ha, which has major economic implications. KPMG (2021) estimated that the 30% reduction scenario through herd size reductions plus multiple other measures would imply a 25% decrease in profits for average dairy farms (-€17.5K) and 31% profit decrease for average beef farms (-€2.8K). It is evident that new business models are essential to reward animal farms not only for their food production but also for their delivery of ecosystem services and landscape stewardship. When extensifying livestock farms, it is key to adopt a just transition approach to ensure farm community inclusion in decision processes and secure farm income and livelihoods.

Case studies

- Eytemaheert is a 'nature farm' in the Netherlands of 83 ha with cattle used for both dairy and beef production. The farm mission "*It's not the cow, it's how*" expresses the core values of nature-inclusivity and circular nutrient flows. Nutrient cycles are fully closed by feeding cattle only with on-farm produce, and by using all manure on the farm. No external inputs such as fertilizers and pesticides are used, and instead regenerative soil management is practiced. Biodiversity is boosted by providing habitat for farm- and cropland birds and by managing adjacent nature areas in collaboration with the local nature conservation organization. The meat and cheese products are sold directly and independently to consumers via their webshop and local shops.

- Another example closer to home is the rotational grazing system implemented by Kevin McAuley and his son-in-law Derek O'Melvena in Broughshane, County Antrim. By subdividing their pasture into paddocks and rotating animals with the right timing, they have grown their total grass yield by 50-70%, increased pasture quality (higher protein content and digestibility, and lower fiber content) and created high quality silage from excess in paddocks. As a result, cattle growth rates have increased by 0.8 - 1.0 kg of daily liveweight gain. Fertilizer use has also been reduced, lowering the impact on the environment and nitrous oxide emissions. Next to increased forage production, this production system is associated with lower GHG emissions through altered manure deposition, decreased fertilizer, and increased soil carbon sequestration (Grossi et al, 2019).

Methane-reducing feed additives for ruminants

Reducing the volume of methane produced from ruminant enteric fermentation is an essential measure to reduce GHG emissions per animal. Electron receptors such as fumarate, nitrates and sulfates and chemical inhibitors such as 3-Nitrooxypropanol (3NOP) can target methane-producing microbes in the rumen, reducing enteric CH_4 emissions by a significant amount (Beauchemin et al, 2009).

Methane-reducing feed additives for ruminants are still a new technology, with only some additives having been commercialized very recently. Yet, much progress has been made on researching the exact effects and trade-offs of different additives. Recent attention has gone to ionophores (e.g. monensin), plant bioactive compounds (e.g. tannins) which also reduce ammonia emissions (Jayanegara et al, 2020; Min et al, 2020) and to nitrates, which have shown to reduce CH_4 emissions by 30 to 60% (Jayasundara et al, 2016). However, health risks of tannins and antibiotic resistance associated with the use of ionophores are a barrier to the use of these additives. Additives with 3NOP are a very promising option and have proven to reduce methane emissions in sheep, beef and dairy cattle (Granja-Salcedo et al, 2019). A daily teaspoon of 3NOP in feed can save 1 ton CO_2-eq / cow head / year. In addition, there are no negative effects on consumer safety, animal health and environment (Bampidis et al, 2018). Nevertheless, 3NOP is not a currently available technology in Ireland. It is expected that this measure will be implemented starting 2025 (KPMG, 2021), perhaps even earlier for ruminants which are housed over the winter period. To unlock the full potential of this mitigation measure a substantial number of farmers will need to adopt this consistently over a long period of time.

Another potential feed additive ingredient is seaweed. Seaweed species such as ***Asparagopsis taxiformis*** and ***Asparagopsis armata*** contain bioactive compounds such as CHBr3 (bromoform), which is a strong methane inhibitor. Research has shown that small amounts of seaweed (e.g. 0.1% and 0.2% of Asparagopsis) could reduce enteric CH_4 by up to 99% (Muizelaar et al, 2021). In addition, emerging research is showing that feeding plant material high in tannins could reduce CH_4 as well as ammonia emissions from cattle (Jayanegara et al, 2020; Min et al, 2020). The use of seaweed feed additives is currently mostly in the laboratory and field trial phase, although there have been recent efforts to start implementing this measure on commercial farms.

In terms of co-benefits, especially seaweeds have great benefits for climate adaptation, water quality, and the stimulation of a new agrifood niche market. In addition, seaweed can improve livestock productivity (growth, lactation, gestation) due to it containing many vitamins (A, B, C, D, E), high quality proteins, natural antioxidants, antimicrobials, compounds (containing calcium, phosphorus, sodium, potassium and iodine), and fatty acids (Omega 3 and 6) (Min et al, 2021). This could potentially render ruminants more healthy and resilient to heatwaves and diseases (Vijn et al, 2020). The water quality benefits are mainly at seaweed production sites, and can benefit regional food systems and rural development if production happens in native coastal waters. In fact, Irish coastal waters are excellent for seaweed production, and have traditionally been cultivated there for food and fertilizer. When growing, seaweeds filter nutrients from the water and decrease eutrophication and algal blooms (Troell et al, 1999). Seaweed cultivation in Irish waters can not only supply local livestock markets and provide great

benefits for the climate, but can also provide market and job opportunities for this new niche product. Next to feed additives for ruminants, seaweed is gaining international interest as an ingredient in human food, fertilizers, pharmaceuticals and industrial processes (Khalil et al, 2017)

The main trade-off is regarding extra costs required. The costs of 3NOP, for example, are estimated to be €44/ruminant head/year (KPMG, 2021). Feed additives are expenses on top of conventional expenses, thus further stretching farm incomes. Many farmers might not be able to afford the extra costs or have the incentive to adopt, especially in extensive systems where sustained delivery of additives to grazing animals is more difficult. Thus, when stimulating feed additives as a national effort to meet climate goals, subsidies and financial schemes for environmental practices will likely be crucial. It is known that feed additives are most effective when mixed with grain, hay or silage in feedlots, and to ingested amounts are harder to regulate in pasture-based grazing systems. Thus management options for Irish pasture-based systems should be explored further. Furthermore, more research and market development is required to upscale successfully. Ensuring stable quantity and quality of seaweed at acceptable economic costs and without effects on existing ecosystems will be key amidst the further work needed to prove the abatement potential of these novel feed additives, and deal with safety and legal aspects before commercialization can begin. Nevertheless it is clear that feed additives have a lot of potential to reduce enteric emissions from ruminants.

Case studies

- Bovaer® is an innovative feed additive developed by DSM that has been approved earlier this year as a marketable feed additive for dairy cows in the EU. This additive includes 3NOP and has been found to reduce methane emissions from cattle by 30%. DSM has started a large-scale pilot project together with Friesland Campina, a major dairy cooperative in the Netherlands, and Agrifirm. Agrifirm will supply 200 participating dairy farms to gain practical experience with the additive and work towards creating climate neutral dairy products. Providing the results in early 2023 are positive, the use of Bovaer® will be further upscaled from 2023.

- Morrisons is the fourth largest supermarket chain in the United Kingdom and is currently working with Queen's University Belfast on a three-year trial to investigate the use of indigenous seaweed from UK and Irish coastlines in reducing methane emissions of cattle in the UK. Morrisons has set a business target in 2020 to achieve net zero emissions within its UK agriculture supply chain (farmers) by 2030. Intermediate lab results are positive and indicate that indigenous seaweed is not only effective in reducing methane, but is potentially preferable to the imported red seaweed tested in other studies which contains the harmful compound bromoform. Indigenous seaweed also contains phlorotannins which are safe, anti-bacterial and improve immunity and so have additional health benefits for cows. Morrisons is aiming to apply this additive in practice with participating beef farmers.

Plant-based production systems

Next to measures on *how* to produce food, measures on what Ireland produces are also essential to reduce the carbon footprint of the agrifood sector. Low-carbon commodities and supply chains can play a significant impact to achieve climate goals. The majority of Ireland's farms produce animal-based products, while their production causes much higher GHG emissions than plant-based products (Poore and Nemecek, 2018). Plant-based products are one of the most high-impact climate mitigation measures feasible for the agrifood sector (Kennedy et al, n.d.; IPCC, 2020; German et al., 2021).

Transitioning away from animal production systems requires diversification and integration of production systems, market shifts, and dietary changes. This relies on a food system approach rather than solely a farming system approach. The interaction between food supply, distribution and demand is a balancing act. On the supply side, it would require moving from animal farming systems towards plant production systems, where appropriate. In many cases, the mix of crops and animals in integrated production systems is beneficial on multiple scales (e.g. silvopastoral systems). Temporary grasslands and feed crops can be replaced with food crops, such as grains, vegetables, fruit, fungi, nuts and leguminous crops - depending on soil types and the local climate. It should be noted that the conversion of permanent grassland into arable systems can result in a net loss of soil organic carbon due to soil disturbance. These carbon emissions can partly be offset by using regenerative farming practices such as cover cropping, residue incorporation and minimal tillage. Although the soil carbon emissions from converted permanent grasslands are likely still lower than emissions associated with conventional livestock production, the maintenance of permanent grasslands should be encouraged, with plant-based production happening on land currently used for temporary grassland and feed crops. On the demand side, more plant-based diets by Irish consumers is helpful, but it should be acknowledged that the majority of Irish animal products are being exported, primarily to the UK and EU. Therefore, dietary trends in those countries are even more critical to decarbonising Irish agrifood systems as domestic consumer behavior changes. This measure would imply a market shift away from the animal product-dominated export market towards plant-based international and local markets.

The global climate mitigation potential of dietary changes is estimated as 0.7-8.0 Gt CO_2-eq/year by 2050 (IPCC, 2020). This is mainly related to release of several million km2 land for grazing and feed production, plus the reduced amount of animals, which together have a major carbon footprint. The mitigation potential is even more abundant where locally produced plant-based food is used, which minimizes the environmental impact of transport.

Plant-based production systems have multiple co-benefits, especially for water and air quality. Local air quality is generally improved in the absence of NH3- and NOx-emitting livestock, which cause air pollution associated with human health risks (Himics et al, 2022). Water quality may improve at locations where nitrogen leaching from excess manure and synthetic N fertilizers application on pastures caused water eutrophication issues. However, conventional arable farming also uses significant amounts of nitrogen fertilizers (Buckley et al. 2018), which often leads to similar problems. In order to ensure water quality alongside plant-based systems, it is essential to minimize overapplication of synthetic N fertil-

izers and instead use other soil fertilization techniques such as crop rotations with N-fixing plants (see section 3.2.3). Regarding diets, plant-based is more nutritious and has major human health benefits compared to conventional animal-based diets (Springmann et. al, 2016).

Two key trade-offs are already highlighted above, regarding potential carbon emissions from grassland conversion and issues with nitrogen leaching from arable production systems. It is essential that transitions towards plant-based production systems are well designed to match local soil and ecosystem conditions. Some other measures outlined in this report, especially regarding N-fixing plants, agroforestry and paludiculture, can be considered as more detailed guiding principles for future-proof plant-production systems in Ireland. The other main trade-off is economically, as animal-based products currently are the basis of Irelands' agrifood market - especially export markets. Transitions to plant-based or mixed plant/animal production systems require a shift in value chains and development of new markets.

Case studies

- The Palopuro Agroecological Symbiosis Farm is an interesting example of a mixed farm, where the biomass, nutrient and energy flows are connected locally. The energy-positive, circular food production system is located in the village of Palopuro near the town of Hyvinkää, Southern Finland. The farm entails an organic cereal farm, an organic vegetable farm, an organic hennery, a bakery, and a biogas plant. Silage from green manure is the main feedstock for the plant, along with chicken manure and horse manure from nearby stables. Through anaerobic digestion biogas is formed, which is used to dry grain and as fuel for the bakery ovens. The remainder of the biogas is upgraded to biomethane for use as fuel for the farm and for sale at a gas station built next to the plant. The nutrient-rich digestate that is formed in the plant is used as organic fertilizer on the field, next to the green manure and commercial organic fertilizers.

- Refarm'd is a scheme that helps dairy farmers move away from milk production to plant-based production systems. Farmers transition to plant-based drink production and processing, sourcing the needed ingredients from local producers or eventually from their own farm. At the same time, part of their farmland is converted into an animal sanctuary. The high quality, minimally processed, organic, fresh, sugar- and additive-free milk yields a good income. Next to benefits for cattle ethics, human health and environment and ecosystem services, farmers benefit from an exit strategy from the dairy industry to join the booming plant-based market. With a growing number of participating farmers in Europe, Canada, the USA and central America this is an innovative example of supporting more plant-based production and diets. A similar project is the Transfarmation Project launched by Mercy for Animals (MFA) to help farmers currently raising animals on a large scale grow crops such as hemp, mushrooms, and hydroponic lettuce instead.

Nitrogen from crop system diversification and N-fixing plants

Synthetic nitrogen fertilizer is one of the main sources of GHG emissions, which is caused by CO_2 emissions during the manufacturing process and N_2O emissions from agricultural soils during and after application. Leaching of synthetic nitrogen fertilizers is the main driver of poor water quality caused by eutrophication. The livestock and arable sectors are the main consumers of nitrogen fertilizers. Even though only 6% of Irish farms are arable (compared to 89% livestock), they generally use almost twice as much nitrogen fertilizer (83 N kg/ha for grasslands vs 158 N kg/ha for cereal crops) (Buckley et al. 2018). Thus, efforts to decrease N fertilizer use as a climate mitigation measure should target both sectors.

Regarding arable farming systems, synthetic nitrogen fertilizer usage can be decreased or even eliminated by incorporating nitrogen fixing plants (*Fabaceae* or *Leguminosae*, commonly known as the legume, pea, or bean family) into crop rotations or using these as cover crops and incorporating them later as green manure for the soil. By increasing soil nitrogen levels, less synthetic N fertilizer is needed. For farms that have short growing seasons and minimal management windows, certain fast growing legumes and non-legume cover crops (or mixes) can be used (e.g. cereals, grasses, and brassicas) next to other options such as slow-release fertilizers and precision farming. Crop system diversification is another approach to reduce reliance on synthetic nitrogen fertilizer. Diversification can be expressed in the form of genetic (using different species and varieties), spatial (different species in a physical arrangement) or temporal (rotation) diversity (Ditzler et al, 2021). An example of spatial diversification is strip intercropping, where a cultivated field is partitioned into long, narrow strips which are alternated in a crop rotation system. This practice can yield similar and even higher yields due to beneficial crop-interactions and overyielding, and requires less fertilizer and pesticides (Maitra et al, 2021). Crop system diversification is increasingly being researched and implemented to optimize the climate mitigation potential and enhance provision of ecosystem services and resilience to climate change.

Regarding livestock farming systems, synthetic nitrogen fertilizer usage on grasslands can be decreased or even eliminated with optimal grassland and grazing management. Also here nitrogen-fixing plants, such as clover, are impactful NbS. Whereas conventional perennial ryegrass grasslands rely on synthetic fertilizers, more diverse grasslands with native grass and herb species thrive on manure alone. Swards containing a diverse range of grass, legume and herb species can even exceed the biomass of monocultural perennial ryegrass swards, even with reduced N inputs (Jaramillo et al, 2021). Research using a cattle and sheep co-grazing system showed dry matter production and growth rate of multispecies swards was greater than perennial ryegrass and pre-existing permanent pasture despite reduced nitrogen rates and periods of below average rainfall (Shackleton et al, n.d.).

The climate mitigation potential of crop rotation and cover crops, particularly with legumes is very high. It has been estimated that cover crops have the potential to mitigate climate change by ~100 to 150 g CO_2-eq per m^2/year, which is higher than the impact from transitioning to no-tillage farming (Kaye & Quemada, 2017). Good grassland management can also result in carbon sequestration of up to 40 g C per m2/year (FAO, 2010), although this also depends on climate and grass types (Abdalla et al, 2018). In

addition, by increasing clover proportions in grasslands and reducing fertilizer application, a 33% reduction on kg N_2O-N / kg grass dry matter can be achieved (Fuchs et al, 2018). The mitigation impact of crop system diversification is highly dependent on the type of system that is implemented. In general diverse agroecosystems can improve soil structure and fertility, producing high yields and subsequently reducing the need for over-applying nitrogen fertilizer. This results in more carbon sequestration and less N_2O emissions.

The co-benefits of replacing synthetic N fertilizer by more natural N fertilization techniques are extensive. Measures such as crop system diversification, crop rotation, cover crops and incorporation of crop residues improve e.g. soil fertility through N fixation, erosion control, soil organic matter contents, soil water holding capacities, reduce nutrient leaching, and increase of yields over the medium to long term. Not to mention that these practices increase the adaptive capacity of these systems to shocks such as weather extremes, pests and diseases or shocks in the market, by diversifying incomes (spreads risk, provides forage) and reducing income spent on fertilizer. There are also clear co-benefits for water and air quality. Lower fertilizer application will mean reduced NH_3 (which also indirectly contributes to climate change) emissions and thus reduced PM in the air - improving air quality for human health. Less synthetic N fertilizer runoff and nutrient leaching into local water bodies will directly improve water quality. Moreover, the use of nitrogen-fixing plants reduces farm input costs regarding synthetic fertilizer and crop diversification provides income diversification - both improving farm financial resilience.

The trade-offs of crop system diversification include the risk of yield losses per species due to reduced cropping intensity, while total yields of the diverse range of new species can be the same or even higher (MacLeod et al, 2015). Cover crops take up space and time, while financial benefits are not always evident. In addition, diversified cropping and grassland systems are more complex and require an innovative approach regarding farm design and management. The adoption and effectiveness of these measures will also depend on the educational opportunities and tools provided to farmers to support farm decision-making around cover crops.

Case studies

- Tom Short is a tillage and mixed livestock farmer from Newtownmountkennedy Co. Wicklow. On his farm he chooses to grow cover crops i.e. catch crops over the winter period to improve soil quality for the feed value the crop will provide his livestock. The root system of the cover crop not only increases the soil structure and organic matter of the soil but also increases soil biodiversity and prevents the loss of nitrogen and run-off of nutrients to nearby water bodies. Tom undertook this action as part of the Low-carbon Agri-environmental Scheme (GLAS) in 2015 as part of the Rural development Programme 2014-2020.

- ERF grows organically certified agricultural crops in an innovative way in the province of Flevoland, the Netherlands. The farm covers 1500ha and is part of the global network of Lighthouse Farms. It produces 20 different organic arable and vegetable crops such as cereals, peas, spinach and beans. To make their production system more sustainable and future proof they are trying to diversify their cropping systems spatially and temporally by implementing strip intercropping on 100ha. This form of cropping system is of sufficient scale to be compatible with modern machinery for cultivation and processing. The increased crop diversity at the field level requires very little use of synthetic pesticides due to natural pest control, allows more efficient nutrient use and improves biodiversity and agro-ecosystem services. The rotation of different crops over time also yields green manure and suppresses weeds. This farm exemplifies the potential of maintaining large-scale profitable agriculture while also integrating organic farming and nature considerations.

Agroforestry

Agroforestry has extremely high climate mitigation potential. Agroforestry is a collective name for intentionally-designed land-use systems where perennial plants (trees, shrubs) are combined with crops and/or livestock (Center for Agroforestry, 2021). There are three main types of agroforestry: silvopastoral (trees and pasture/livestock), silvo-arable (trees and annual crops), and agrosilvopastoral (combining trees, animals and crops). Agroforestry types such as food forests (mostly fruit trees, nut trees and herbs), forest farming (crop cultivation within a forest, such as harvesting of forest fungi), landscape elements (hedgerows, shelterbelts, trees for water protection) and homegardens (trees and food production in small areas) fall under silvo-arable systems.

All three agroforestry systems are suitable to the Irish landscape, especially silvopastoral systems, as livestock grazing is one of the most common land uses. Transitioning to agroforestry systems, especially food forests, requires a significant farm redesign and change in farm management. For example, silvo-pastoral systems require planting of trees on pastureland, and silvo-arable systems add hedgerows within cropping fields. The entire production system is redesigned and (re-)planted in such a way

that multiple different food-producing species can grow together using synergies. Currently, there is a specific grant category within the DAFM Afforestation Scheme in which landowners can apply for grant support to plant an area of agroforestry.

The climate mitigation potential of agroforestry ranges across production systems and regions, but has the astonishing potential to globally mitigate between 2.3-9.6 Gt CO_2-eq/year by 2050 (Shukla et al, 2019). Climate mitigation takes place due to enhanced carbon storage in soils and biomass (Kim et al, 2016). The presence of perennials (trees and shrubs) provide the ability to store much more carbon in soils and vegetation, compared to cropping systems with annuals (which usually results in net loss of soil carbon). Kay et al. (2019) identified that 17% of Ireland's agricultural land (over 7,000 km2), particularly on pastures, has major potential for positive impact from agroforestry implementation. The mitigation potential of these pastures lies between 16 and 635 t CO_2-eq/km2/year, depending on the agroforestry systems chosen. If agroforestry would be applied to those 17% high potential pastures, the climate mitigation potential of agroforestry in Ireland could be up to 4.4 million t CO_2-eq/year. More concretely, the Irish Agroforestry Forum concluded that silvo-pastoral systems with Ash trees in pastures (storing 3.2 t C/ha/year; McAdam, 2020) plus hedgerows can support carbon-neutral beef production for approximately 2 Livestock Units per hectare. Hence, there is a huge potential for offsetting unavoidable GHG emissions by enhancing carbon storage in soils, crops and trees through agroforestry systems.

Co-benefits of agroforestry constitute positive impacts on climate adaptation, biodiversity, soil fertility, pest mitigation and income diversification (Tschora & Cherubini, 2020). In general, agroforestry has a positive effect on soil quality and soil water management, which enhances climate change resilience. Trees in silvo-pastoral systems can provide shade to animals during heat waves, and in silvo-arable systems they function as wind and direct sun breaks for crops. The diversified production systems also provide synergies between plants, which can increase total biomass yields. The diverse range of harvestable products provides alternate sources of income on the farm, making primary producers less reliant on one product and more resilient to harvest failures.

Regarding trade-offs, there is some debate as to whether agroforestry reduces yields. This seems dependent on the combination of trees and crops, as well as the soil type and location (Ivezic et al, 2021). Crop yields can increase for example when trees stand adjacent to cropland, due to improved rainwater management and reduced erosion. Decreased crop yields can occur for example where trees compete for light, water and nutrients. It should be mentioned, however, that total biomass production increases, even where yields for single products may decrease.

Case studies

- Eastbrook farm in the UK has planted 19 different species of trees and nuts on their field and has implemented an alley cropping field that will provide shade during hot weather, shelter during the winter and browse for cattle. Even though a diverse agroforestry system creates more complexity, it ultimately yields a more resilient and productive system, regenerating soil and retaining moisture, improving biodiversity, and providing a diversified value-added income from the range of different produce to sell. Animals feeding on tannin-rich trees can also help reduce methane production by the ruminants (Min et al, 2020).

- Porcus Natura in Portugal is a regenerative farm of 700ha owned by Francisco Alves. The farm hosts an agroforestry system characterized by a combination of low-density cork trees, pastures and arable fields. A mixture of vegetables, fruit and multiple animal species (Alentejano pigs, Angus beef cows, Serpentina goats and Merino sheep) are produced here. The farm uses an optimized rotational grazing system, entailing the daily rotation of spaces covered by animals, to improve the quality of the pasture, regenerate the soil and reduce emissions. In addition, no pesticides and tillage practices are used. This way, they can prevent groundwater pollution, increase biodiversity, increase soil moisture and the carbon storage capacity of the soil. Porcas Natura is an example of a new business model based on extensification whereby a more diverse production system with different animal and plant species can decrease farm emissions.

- In the Netherlands multiple food forests have been established. Notable examples are food forest Schijndel, food forest Ketelbroek (also houses a knowledge center), and food forest Eet Meerbosch. Ketelbroek was a bare corn field when it started in 2009, and now showcases a flourishing agroecosystem with >200 edible tree and shrub species. Schijndel is the largest food forest of 20 ha and works closely with the HAS university to gain knowledge on new combinations of agriculture and about further increasing economic feasibility and scalability of these systems. With multiple vegetation layers, and no tillage, livestock, pesticides or fertilizer, these systems yield multiple benefits: diverse produce, increased soil fertility, carbon sequestration, habitat for pollinators, and natural pest control.

Rewetting peatlands: paludiculture

Paludiculture is farming on rewetted peat soils. It offers great climate mitigation potential compared to drained peatland production systems, while maintaining profitable business models (de Jong, 2021; van der Meer, 2021; Wichmann, 2021). Paludiculture has most benefits in lowland peat soil areas, where currently 85% of soils have been drained to create favorable conditions for forestry (31%), agriculture (mainly grassland) (28%), turf cutting (17%), and energy production (6%) (Wilson, 2021). Draining peatlands enables access by machinery (for peat cutting or agriculture), for livestock grazing and growth of plant species that do not prefer waterlogged soils. This causes significant carbon emissions because the removal of permanently waterlogged conditions in the soil facilitates the oxidative decomposition of organic matter.

Raising the water table to rewet the peat soil and reduce peat soil carbon emissions induces wetland conditions, which are unsuitable for conventional production systems. As an alternative, paludiculture with wetland crops is a profitable agricultural production system on these rewetted soils. Paludiculture provides opportunities for over 80 crops suitable as food, fodder, medicinal use, raw material and energy provision (Milner & Stuart, 2022). The most iconic example crop is reed, which was produced in the UK for centuries to provide thatch for houses. Commercial paludiculture is already practiced with for example water buffalo (for meat) and cattail farming (for insulation/construction material). Research currently focussed on the agronomic and market potential of many other crops such as BulrushTypha (can be used as building material, textile and bioenergy), Sphagnum (can be used to replace peat as growing medium and as biomedical or industrial chemical), and food crops including bilberry, celery, cranberry, nettle, sedge, grans, sweet grass grains, watercress, and water pepper (Mulholland et al, 2020).

The climate mitigation potential of paludiculture in temperate climates, such as Ireland, can be major. Current CO_2 emissions from Irish peatlands is estimated to be 3 Mt C/year, whereas the mitigation potential of paludiculture per hectare is estimated around 4.7 t C/ha/year for grasslands, 2.1 t C/ha/year for peat extraction, and 1 Mt C/ha/year from peat-related energy production (Wilson et al, 2013). Eventually rewetted peatlands can become carbon sinks once more, although this depends on the nutrient status of soils. While rewetted nutrient poor soils will become a carbon sink (emitting –0.37 t C/ha/year), rewetted nutrient rich soils are more likely to remain a carbon source for a while (emitting 1.75 t C/ha/year) (Wilson et al, 2013). Next to nutrient status, successful rewetting and thus the exact emission reduction potential will depend on the topography, peat type, vegetation cover, average annual water table depth, and restoration practices other than rewetting (Hiraishi et al, 2014).

Co-benefits of paludiculture are significant for climate adaptation, enhancing soil organic carbon and biodiversity (Vroom et al, 2022). At the same time, restored water and nutrient cycles associated with rewetted peatlands and vegetation can prevent nutrient and pollutant losses. Next to reducing GHG emissions from the soil, there is also carbon uptake when the peat starts to regrow (Tanneberger et al, 2022). Indirectly there can also be benefits for air quality as a transition away from domestic peat extraction may translate to reduced sale and use of peat for household heating. Furthermore, there

are also possibilities to combine rewetting of soils with renewable energy production. Excess production can be sold to the main network. A study by Wageningen University showed that establishing solar power holds the potential to mitigate around 5 t CO_2-eq/ha/year (Verstand et al, 2020).

Trade-offs depend on the new type of production system introduced on the rewetted soil. It should be recognized that introduction of paludiculture implies a significant transformation of the farm design, management and business model. Not all paludiculture crops can compete economically with dryland alternatives, as biomass production is often lower and value chains not yet developed. In order to boost and scale this relatively new and innovative measure, paludiculture requires attention from agronomic research, targeted value chain development, public payment for ecosystem services, and inclusive landscape planning processes.

Case studies

- In Germany, organic farm Gut Darss keeps water buffalos on restored coastal peatland. The herd contains over 250 water buffalos. The water buffaloes graze on the wet, regularly flooded coastal meadows, enabling peat formation and providing buffalo meat. Gut Darss' farm markets the meat directly for premim prices, which creates a *healthy and stable* farm income.

- In Rwanda and the Netherlands, paludiculture with raw materials is very successfully grown and commercialized. In Rwanda, papyrus and bamboo are grown on rewetted soils to restore ecosystems and enhance resilient communities. Bamboo is used as packaging material, hygiene paper, and furniture. Papyrus is used as fodder, mulch and for artisanal handicraft. In the Netherlands, cattail is grown for commercial use as insulation and construction material by the private company Better Wetter. The cattail is harvested during winter with a special caterpillar mower.

1.4 Recommendations

As this report has made clear, amidst the challenges of the climate crisis lies a great opportunity to adapt the agrifood sector in Ireland with multiple co-benefits. It is evident that the Irish agrifood sector has a huge challenge ahead to reduce their current contribution of 37.5% to national GHG emissions towards net-zero in 2050. Particularly the livestock sector plays a core role in this mission given their responsibility for the far majority of emissions today.

When considering effective measures to mitigate the agrifood sector's carbon emissions, while also generating co-benefits regarding other urgent challenges - in this case water and air quality - two guiding principles are key. Firstly, taking a food system approach in order to reconsider *what* is produced and *why*. Rather than tweaking current production systems to achieve mild carbon efficiency gains per

Credit: Shutterstock

product, while production volumes continue to rise and outweigh the emission gains, measure packages should culminate in a net reduction of emissions for the entire sector. There, it is essential to first consider the carrying capacity of Ireland's soil-water systems and the climate goals, when (re-)designing future-fit food production systems. Moreover, considering the interactions and effects of the multiple levels of food systems - production, processing, distribution and consumption - is key to ensure food and nutrition security, equitable value chains, and positive environmental outcomes. Second, the guiding principle of Nature-based Solutions (NbS) as a preferred range of measures before more technology-based solutions. NbS such as restoring peatland soils through paludiculture and planting trees through agroforestry embed the potential to reduce one-third of global GHG emission reductions required. These natural solutions already exist and require minimal investment in innovation - just smart implementation of nature's best 'technologies' into well-designed new agrifood systems.

The 6 measures highlighted in this chapter were: extensive ruminant farming (with reduced herd size), methane-reducing feed additives for ruminants, plant-based production systems, nitrogen from crop system diversification and N-fixing plants, agroforestry, and paludiculture (rewetting peatlands). All these measures have major climate mitigation potential, alongside multiple co-benefits for climate adaptation, water quality, air quality. Besides the benefits, trade-offs and challenges also come to play - mostly regarding productivity, economic profitability and the need to develop new markets.

These measures should be considered as a package rather than individual options. The Irish agri-food system is complex and requires multiple systemic changes to meet their climate goals. With e.g. agroforestry or ruminant feed additives alone, net zero by 2050 won't be met. The combination of all measures is key. Some measures have great potential for combined application per field or farm, such as livestock extensification & agroforestry (e.g. silvopastoral systems) or plant based production systems & N-fixing plants (e.g. legume and bean cultivation).

It should be acknowledged that these measures together add up to a rather substantial and challenging agrifood system transformation. However, they highlight an essential package of actions for Ireland to achieve their climate goals while also achieving other essential environmental goals.

The implementation of the discussed measures, and also those left out of scope here, comes with great implications for farming communities and other supply chain stakeholders. A Just Transition approach is essential to enable the changes in an inclusive and equitable manner. Support for farms to overcome transition barriers and adopt effective measures will be crucial. This can come in the form of knowledge exchange and agronomic support, but also the development and stimulation of new business models and markets. This may at times require direct governmental support; with special attention for eco-schemes to financially reward farms with climate- and nature-positive outcomes. For some measures mentioned above, especially for paludiculture, agroforestry and feed additives, continued research is needed on cost-benefits and best practices for implementation in various contexts. Raising public awareness on the benefits of plant-based diets, both for the climate and for public health, will help to shift consumption patterns and transform the food system in the long term.

1.5 References

- Abberton, M., Conant, R., & Batello, C. (2010). Grassland carbon sequestration: management, policy and economics. Food and Agriculture of the United Nations, Rome. https://www.fao.org/3/i1880e/i1880e00.pdf
- Abdalla, M., Hastings, A., Chadwick, D. R., Jones, D. L., Evans, C. D., Jones, M. B., ... & Smith, P. (2018). Critical review of the impacts of grazing intensity on soil organic carbon storage and other soil quality indicators in extensively managed grasslands. Agriculture, Ecosystems & Environment, 253, 62-81. https://doi.org/10.1016/j.agee.2017.10.023
- Baek, B. H., & Aneja, V. P. (2005). Observation based analysis for the determination of equilibrium time constant between ammonia, acid gasses, and fine particles. International journal of environment and pollution, 23(3), 239-247. https://doi.org/10.1504/IJEP.2005.006864
- Bampidis, V., Azimonti, G., Bastos, M. D. L., Christensen, H., Dusemund, B., ... & Pizzo, F. (2021). Safety and efficacy of a feed additive consisting of 3 nitrooxypropanol (Bovaer® 10) for ruminants for milk production and reproduction (DSM Nutritional Products Ltd). EFSA Journal, 19(11), e06905. https://doi.org/10.2903/j.efsa.2021.6905
- Beauchemin, K.A., cAllister, T.A., McGinn, S.M., 2009. Dietary mitigation of enteric methane from cattle. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 4, 1-18. https://doi.org/10.1079/PAVSNNR2009403
- Bermingham, D. (2022). Fodder crises 'twice as likely' in coming decades. Irish Examiner. https://www.irishexaminer.com/farming/arid-40830509.html
- Bogunovic, I., Kljak, K., Dugan, I., Grbeša, D., Telak, L. J., Duvnjak, M., ... & Pereira, P. (2022). Grassland Management Impact on Soil Degradation and Herbage Nutritional Value in a Temperate Humid Environment. Agriculture, 12(7), 921. https://doi.org/10.3390/agriculture12070921
- Buckley, C. and Donnellan, T. (2022). National Farm Survey - 2021 Sustainability Report. Teagasc: Agricultural Economics and Farm Surveys Department. https://www.teagasc.ie/publications/2022/national-farm-survey---2021-sustainability-report.php
- Buckley, C., Dillon, E., Moran. B. & Lennon, J. (2018). Trends in fertiliser use. Teagasc. https://www.teagasc.ie/media/website/publications/2018/15-Trends-in-fertiliser-use.pdf
- Casasús, I., Riedel, J.L., Blanco, M., Bernués, A. (2012). Extensive livestock production systems and the environment. In: Casasús, I., Rogošiç, J., Rosati, A., Štokoviç, I., Gabiña, D. (eds) Animal farming and environmental interactions in the Mediterranean region. EAAP – European Federation of Animal Sciences, vol 131. Wageningen Academic Publishers, Wageningen. https://doi.org/10.3920/978-90-8686-741-7_9

- Central Statistics Office. (2016). Farm Structure Survey 2016. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-fss/farmstructuresurvey2016/da/lu/
- Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). Nature-based solutions to address global societal challenges. IUCN: Gland, Switzerland, 97, 2016-2036.
- de Jong, M., van Hal, O., Pijlman, J., van Eekeren, N., & Junginger, M. (2021). Paludiculture as paludifuture on Dutch peatlands: An environmental and economic analysis of Typha cultivation and insulation production. Science of the Total Environment, 792, 148161. https://doi.org/10.1016/j.scitotenv.2021.148161
- Department of Agriculture, Food and Marine. (2015). Food Wise 2025: A 10 year Vison for the Irish Agri-food Industry. DAFM. https://assets.gov.ie/109083/cf17ada8-e95a-4a10-b228-7743a8b68c44.pdf
- Department of Agriculture, Food and Marine. (2022). Annual Review and Outlook for Agriculture, Food and the Marine 2022. Economics and Planning Division. https://assets.gov.ie/238928/75008324-6f05-4f30-a9d3-6a9259371771.pdf
- Dillon, E., Donnellan, T., Moran B. & Lennon, J. Teagasc National Farm Survey 2021: Final Results. Teagasc: Agricultural Economics and Farm Surveys Department. https://www.teagasc.ie/media/website/publications/2022/Teagasc-National-Farm-Survey-2021.pdf
- Ditzler, L., van Apeldoorn, D. F., Schulte, R. P., Tittonell, P., & Rossing, W. A. (2021). Redefining the field to mobilize three-dimensional diversity and ecosystem services on the arable farm. European Journal of Agronomy, 122, 126197. https://doi.org/10.1016/j.eja.2020.126197
- Domínguez, I. P., Fellmann, T., Weiss, F., Witzke, P., Barreiro-Hurlé, J., Himics, M., ... & Leip, A. (2016). An economic assessment of GHG mitigation policy options for EU agriculture. Report No. JRC101396 (Publications Office of the European Union, 2016). https://www.researchgate.net/profile/Thomas-Fellmann/publication/304571122_An_economic_assessment_of_GHG_mitigation_policy_options_for_EU_agriculture_EcAMPA_2/links/5773993908aeb9427e23dd3a/An-economic-assessment-of-GHG-mitigation-policy-options-for-EU-agriculture-EcAMPA-2.pdf
- Duffy, P., Black, K., Hyde, B., Ryan, A.M., Ponzi, J., & Alam, S. (2018). Ireland National Inventory Report 2018. Greenhouse gas emissions 1990-2016 reported to the United Nations Framework Convention on Climate Change. https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/Ireland-NIR-2018.pdf
- European Court of Auditors. (2021). Common Agricultural Policy and climate Half of EU climate spending but farm emissions are not decreasing. ECA. https://www.eca.europa.eu/Lists/ECADocuments/SR21_16/SR_CAP-and-Climate_EN.pdf
- European Environmental Agency. (2022). Air quality in Europe 2022. EEA Web Report. https://www.eea.europa.eu/publications/air-quality-in-europe-2022
- Fitzgerald, C. (2019). Dairy in the Irish economy! Teagasc. https://www.teagasc.ie/media/website/publications/2019/Dairy-in-the-Irish-economy.pdf
- Flood, S. (2013). Projected economic impacts of climate change on Irish agriculture. Stop Climate Chaos, Ireland. https://www.stopclimatechaos.ie/assets/files/pdf/projected_economic_impacts_of_climate_change_on_irish_agriculture_oct_2013.pdf
- Fuchs, K., Hörtnagl, L., Buchmann, N., Eugster, W., Snow, V., & Merbold, L. (2018). Management matters: testing a mitigation strategy for nitrous oxide emissions using legumes on intensively managed grassland. Biogeosciences, 15(18), 5519-5543. https://bg.copernicus.org/articles/15/5519/2018/
- García, W.A. & Dwyer, N. (2020). The Status of Ireland's Climate 2020. EPA; Met Eireann; Marine Institute; UCC; Environmental Research Institute; MaREI. https://www.met.ie/cms/assets/uploads/2021/08/The-Status-of-Irelands-Climate-2020.pdf
- German, R., Raoult, J., Schmid, C., Mandl, N., Peglidou, P. (2021). Agricultural climate mitigation policies and measures: Good practice, challenges, and future perspectives. EEA. https://www.eionet.europa.eu/etcs/etc-cme/products/etc-cme-reports/etc-cme-report-6-2021-agricultural-climate-mitigation-policies-and-measures-good-practice-challenges-and-future-perspectives/@@download/file/ETC_CME_Eionet%20report%202021_Agriculture_PaMs%20analysis%2020220510.pdf
- Government of Ireland. (2021). CLIMATE ACTION PLAN 2021: Securing Our Future. Department of the Environment, Climate and Communications. https://assets.gov.ie/224574/be2fecb2-2fb7-450e-9f5f-24204c9c9fbf.pdf
- Granja-Salcedo, Y. T., Fernandes, R. M., Araujo, R. C. D., Kishi, L. T., Berchielli, T. T., Resende, F. D. D., ... & Siqueira, G. R. (2019). Long-term encapsulated nitrate supplementation modulates rumen microbial diversity and rumen fermentation to reduce methane emission in grazing steers. Frontiers in Microbiology, 10, 614. https://doi.org/10.3389/fmicb.2019.00614

- Grossi, G., Goglio, P., Vitali, A., & Williams, A. G. (2019). Livestock and climate change: impact of livestock on climate and mitigation strategies. Animal Frontiers, 9(1), 69-76. https://doi.org/10.1093/af/vfy034
- Hennessy, T. 2010. The impact of climate change on Irish farming. Teagasc. https://www.teagasc.ie/media/website/publications/2010/the_impact_of_climate_change_on_irish_farming_5623.pdf
- Himics, M., Giannakis, E., Kushta, J., Hristov, J., Sahoo, A., & Perez-Dominguez, I. (2022). Co-benefits of a flexitarian diet for air quality and human health in Europe. Ecological Economics, 191, 107232. https://doi.org/10.1016/j.ecolecon.2021.107232
- Ho, L., Jerves-Cobo, R., Barthel, M., Six, J., Bode, S., Boeckx, P., & Goethals, P. (2020). Effects of land use and water quality on greenhouse gas emissions from an urban river system. Biogeosciences Discussions, 1-22. https://doi.org/10.5194/bg-2020-311
- P.R. Shukla, J. Skea, R. Slade, R. van Diemen, E. Haughey, J. Malley, M. Pathak, J. Portugal Pereira (eds.) Technical Summary, 2019. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M, Belkacemi, J. Malley, (eds.)]. In press.
- IPCC, 2020: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press
- Ivezić, V., Yu, Y., & Werf, W. V. D. (2021). Crop yields in European agroforestry systems: a meta-analysis. Frontiers in Sustainable Food Systems, 5, 606631. https://doi.org/10.3389/fsufs.2021.606631
- Jaramillo, D. M., Sheridan, H., Soder, K., & Dubeux Jr, J. C. (2021). Enhancing the Sustainability of Temperate Pasture Systems through More Diverse Swards. Agronomy, 11(10), 1912. https://doi.org/10.3390/agronomy11101912
- Jayanegara, A., Yogianto, Y., Wina, E., Sudarman, A., Kondo, M., Obitsu, T., & Kreuzer, M. (2020). Combination effects of plant extracts rich in tannins and saponins as feed additives for mitigating in vitro ruminal methane and ammonia formation. Animals, 10(9), 1531. https://doi.org/10.3390/ani10091531
- Jayasundara, S., Ranga Niroshan Appuhamy, J. A. D., Kebreab, E., & Wagner-Riddle, C. (2016). Methane and nitrous oxide emissions from Canadian dairy farms and mitigation options: An updated review. Canadian Journal of Animal Science, 96(3), 306-331.https://doi.org/10.1139/cjas-2015-0111
- Kay, S., Rega, C., Moreno, G., den Herder, M., Palma, J. H., Borek, R., ... & Herzog, F. (2019). Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe. Land use policy, 83, 581-593. https://doi.org/10.1016/j.landusepol.2019.02.025
- Kaye, J. P., & Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. A review. Agronomy for sustainable development, 37(1), 1-17. https://doi.org/10.1007/s13593-016-0410-x
- Kennedy, E., McCue A., Sleckman, M., Pelekh, N. & Shaw, B. (n.d.). CIRCULAR AGRIFOOD: Potential of Circular Economy Actions to reduce Greenhouse Gas Emissions. Metabolic. https://www.metabolic.nl/publications/circular-agrifood/
- Khalil, H. A., Saurabh, C. K., Tye, Y. Y., Lai, T. K., Easa, A. M., Rosamah, E., ... & Banerjee, A. (2017). Seaweed based sustainable films and composites for food and pharmaceutical applications: A review. Renewable and sustainable energy reviews, 77, 353-362. https://doi.org/10.1016/j.rser.2017.04.025
- Kim, D. G., Kirschbaum, M. U., & Beedy, T. L. (2016). Carbon sequestration and net emissions of CH_4 and N_2O under agroforestry: Synthesizing available data and suggestions for future studies. Agriculture, Ecosystems & Environment, 226, 65-78. https://doi.org/10.1016/j.agee.2016.04.011
- Koppelmäki, K., Parviainen, T., Virkkunen, E., Winquist, E., Schulte, R. P., & Helenius, J. (2019). Ecological intensification by integrating biogas production into nutrient cycling: Modeling the case of Agroecological Symbiosis. Agricultural Systems, 170, 39-48. https://doi.org/10.1016/j.agsy.2018.12.007
- KPMG. (2021). Ireland's 2030 Carbon Emissions Targets — An Economic Impact Assessment for the Agriculture Sector. Prepared for the Irish Farmers Journal. https://assets.kpmg/content/dam/kpmg/ie/pdf/2021/11/ie-ireland-2030-carbon-emissions-targets.pdf
- Lankoski, J., Ignaciuk, A. & Jésus, F. (2018). Synergies and trade-offs between adaptation, mitigation and agricultural productivity: A synthesis report. OECD Food, Agriculture and Fisheries Papers, No. 110, OECD Publishing, Paris, https://doi.org/10.1787/07dcb05c-en.

- Läpple, D., Carter, C.A., Buckley, C. (2021). EU milk quota abolition, dairy expansion, and greenhouse gas emissions. Agricultural Economics, Volume 53, Issue 1, January 2022, Pages 125-142. https://doi.org/10.1111/agec.12666
- MacLeod, M., Eory, V., Gruère, G., & Lankoski, J. (2015). Cost-effectiveness of greenhouse gas mitigation measures for agriculture: a literature review. https://doi.org/10.1787/18156797
- Maitra, S., Hossain, A., Brestic, M., Skalicky, M., Ondrisik, P., Gitari, H., ... & Sairam, M. (2021). Intercropping—A low input agricultural strategy for food and environmental security. Agronomy, 11(2), 343. https://doi.org/10.1016/j.eja.2020.126197
- McAdam, J. (2020). Evidence base for agroforestry and potential carbon-neutral livestock systems: a 30-years replicated trial comparing grassland, silvopastoral and woodland systems in Northern Ireland. DG CLIMA Carbon Farming Roundtable September 2020. https://www.agroforestry.ac.uk/sites/www.agroforestry.ac.uk/files/JIM%20MCADAM%20%20EU%20CARBON%20FARMING%20INITIATIVES%20ROUND%20TABLE-final-CORRECTED.pdf
- Mielcarek-Bocheńska, P., & Rzeźnik, W. (2021). Greenhouse gas emissions from agriculture in EU countries—state and perspectives. Atmosphere, 12(11), 1396. https://doi.org/10.3390/atmos12111396
- Milner, J. & Stuart, J. (2022). Paludiculture – the future of farming on peat soils? GOV.UK. https://naturalengland.blog.gov.uk/2022/09/30/paludiculture-the-future-of-farming-on-peat-soils/
- Min, B. R., Parker, D., Brauer, D., Waldrip, H., Lockard, C., Hales, K., ... & Augyte, S. (2021). The role of seaweed as a potential dietary supplementation for enteric methane mitigation in ruminants: Challenges and opportunities. Animal Nutrition, 7(4), 1371-1387. https://doi.org/10.1016/j.aninu.2021.10.003
- Min, B. R., Solaiman, S., Waldrip, H. M., Parker, D., Todd, R. W., & Brauer, D. (2020). Dietary mitigation of enteric methane emissions from ruminants: A review of plant tannin mitigation options. Animal Nutrition, 6(3), 231-246. https://doi.org/10.1016/j.aninu.2020.05.002
- Muizelaar, W., Groot, M., van Duinkerken, G., Peters, R., & Dijkstra, J. (2021). Safety and transfer study: Transfer of bromoform present in Asparagopsis taxiformis to milk and urine of lactating dairy cows. Foods, 10(3), 584. https://doi.org/10.3390/foods10030584
- Mukherjee, A., & Agrawal, M. (2017). A global perspective of fine particulate matter pollution and its health effects. Reviews of Environmental Contamination and Toxicology Volume 244, 5-51. https://doi.org/10.1007/398_2017_3
- Mulholland, B., Abdel-Aziz, I., Lindsay, R., McNamara, N., Keith, A., Page, S., ... & Evans, C. (2020). Literature Review: Defra project SP1218: An assessment of the potential for paludiculture in England and Wales. https://lowlandpeat.ceh.ac.uk/sites/default/files/2022-07/Defra-LP2-paludiculture-report-April-2020.pdf
- Murphy, F., Devlin, G., & McDonnell, K. (2015). Benchmarking environmental impacts of peat use for electricity generation in Ireland—a life cycle assessment. Sustainability, 7(6), 6376-6393. DOI:10.3390/su7066376
- National Parks & Wildlife Service. (2014). National Peatlands Strategy. NPWS. https://www.npws.ie/sites/default/files/general/Final%20National%20Peatlands%20Strategy.pdf
- Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., ... & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of the total environment, 579, 1215-1227. https://doi.org/10.1016/j.scitotenv.2016.11.106
- Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992. DOI: 10.1126/science.aaq0216
- Renou-Wilson, F. (2011). BOGLAND - Sustainable Management of Peatlands in Ireland. STRIVE Report No 75 prepared for the Environmental Protection Agency (EPA): Johnstown Castle, Co. Wexford, Ireland. p. 157. https://www.researchgate.net/publication/233924489_BOGLAND_-_Sustainable_Management_of_Peatlands_in_Ireland
- Ricardo-AEA, 2016, Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming, report for Directorate General for Climate Action (European Commission). URL: https://ec.europa.eu/clima/sites/clima/files/forests/lulucf/docs/cap_mainstreaming_en.pdf
- Royal Irish Academy. (n.d.). 2nd Scientific Statement: Climate Change & Irish Agriculture. Irish Committee on Climate Change. https://www.climateireland.ie/web_resource/resources/RIA_Statements/2-Agriculture.pdf
- Shackleton J., Kennedy J., Grace C., Boland T., Schmidt O., Lynch B., Hoffman E., Sheridan H. (n.d.). The impact of sward composition and management on the productivity of herbage under co-grazing of sheep and cattle. Devenish Nutrition; University College Dublin; Wagenigen University and Research. https://www.heartlandproject.eu/herbage-productivity

- Springmann, M., Godfray, H. C. J., Rayner, M., & Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. Proceedings of the National Academy of Sciences, 113(15), 4146-4151. https://doi.org/10.1073/pnas.152311911
- Tanneberger, F., Birr, F., Couwenberg, J., Kaiser, M., Luthardt, V., Nerger, M., ... & Närmann, F. (2022). Saving soil carbon, greenhouse gas emissions, biodiversity and the economy: paludiculture as a sustainable land use option in German fen peatlands. Regional Environmental Change, 22(2), 1-15. https://doi.org/10.1007/s10113-022-01900-8
- Thornton, T. F., & Comberti, C. (2017). Synergies and trade-offs between adaptation, mitigation and development. Climatic Change, 140(1), 5-18. https://doi.org/10.1787/18156797
- Tomlinson, R. W. (2005). Soil carbon stocks and changes in the Republic of Ireland. Journal of Environmental Management, 76(1), 77-93. DOI:10.1016/j.jenvman.2005.02.001.
- Troell, M., Rönnbäck, P., Halling, C., Kautsky, N., & Buschmann, A. (1999). Ecological engineering in aquaculture: use of seaweeds for removing nutrients from intensive mariculture. In Sixteenth international seaweed symposium (pp. 603-611). Springer, Dordrecht. DOI: 10.1007/978-94-011-4449-0_74
- Tschora, H., & Cherubini, F. (2020). Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. Global Ecology and Conservation, 22, e00919. https://doi.org/10.1016/j.gecco.2020.e00919
- van der Meer, P. J., Tata, H., Rachmanadi, D., Arifin, Y. F., Suwarno, A., & van Arensbergen, P. (2021, November). Developing sustainable and profitable solutions for peatland restoration. In IOP Conference Series: Earth and Environmental Science (Vol. 914, No. 1, p. 012032). IOP Publishing. DOI 10.1088/1755-1315/914/1/012032
- Van Grinsven, H. J., Erisman, J. W., De Vries, W., & Westhoek, H. (2015). Potential of extensification of European agriculture for a more sustainable food system, focusing on nitrogen. Environmental Research Letters, 10(2), 025002. DOI 10.1088/1748-9326/10/2/025002
- Verschuuren, J. (2022). Achieving agricultural greenhouse gas emission reductions in the EU post 2030: What options do we have?. Review of European, Comparative & International Environmental Law. https://doi.org/10.1111/reel.12448
- Verstand, D., van der Voort, M., & Vijn, M. (2020). Klimaatbestendige akkerbouw op veengronden: Uitwerking boerderij varianten op economie en broeikasgasemissies. Wageningen University & Research, Open Teelten. https://doi.org/10.18174/535252
- Vijn, S., Compart, D. P., Dutta, N., Foukis, A., Hess, M., Hristov, A. N., ... & Kurt, T. D. (2020). Key considerations for the use of seaweed to reduce enteric methane emissions from cattle. Frontiers in Veterinary Science, 1135. https://doi.org/10.3389/fvets.2020.597430
- Villalba, J. J. (2016). Animal Welfare in Extensive Production Systems. 5m Books Ltd.
- Vroom, R.J.E., Geurts, J.J.M., Nouta, R., Borst, A.C.W., Lamers, L.M.P., Fritz, C. (2022). Paludiculture crops and nitrogen kick-start ecosystem service provisioning in rewetted peat soils. Plant Soil 474, 337–354. https://doi.org/10.1007/s11104-022-05339-y
- Wallace, M. (2020). Economic Impact Assessment of the Tillage Sector in Ireland. School of Agriculture and Food Science University College Dublin. http://tillageindustryireland.ie/wp-content/uploads/2020/07/Economic-Impact-Assessment-of-the-Tillage-Sector-in-Ireland.pdf
- Wichmann, S. (2021). The economics of paludiculture: Costs & benefits of wet land use options for degraded peatlands with a focus on Reed and Sphagnum moss. Universität Greifswald. https://d-nb.info/1261973283/34
- Wilson, D. (2021). Opening Statement for the public session of the Joint Committee on Agriculture and the Marine on the subject of Rewetting of peatlands and the impact on drainage for surrounding farmland. https://data.oireachtas.ie/ie/oireachtas/committee/dail/33/joint_committee_on_agriculture_and_the_marine/submissions/2021/2021-03-02_opening-statement-dr-david-wilson-earthy-matters-environmental-consultants_en.pdf
- Wilson, D., Müller, C., & Renou-Wilson, F. (2013). Carbon emissions and removals from Irish peatlands: present trends and future mitigation measures. Irish Geography, 46(1-2), 1-23. https://doi.org/10.1080/00750778.2013.848542
- World Economic Forum. (2021). Nature and Net Zero. WEF. https://www3.weforum.org/docs/WEF_Consultation_Nature_and_Net_Zero_2021.pdf

2. Carbon Farming

Authors:
Saskia Visser | Ellea Lhermite
Saskia Keesstra

Credit: Shutterstock

Acknowledgements

Climate Kic would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Authors: EIT Climate-KIC: Saskia M. Visser, Ellea Lhermite, Saskia D. Keesstra

Reviewers

Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC)

How to cite this Chapter:

EIT Climate-KIC. (2023). Carbon Farming. Chapter 2 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Carbon Farming

Carbon farming has received widespread attention in recent years. Carbon farming focusses on the management of carbon pools, flows and greenhouse gas (GHG) fluxes at farm level, with the purpose of mitigating climate change. It offers a significant, but uncertain, mitigation potential, can deliver co-benefits to farmers and society, but also carries risks that need to be managed.

The EU acknowledges that sustainable land management will be critical in achieving the climate neutrality objective by 2050 while carbon sinks have been on a declining path over the last decade. To reach the climate neutrality objective of the EU Climate Law, carbon farming has to contribute to increasing the carbon sink capacity of the land sector by 42 million tonnes of CO2 equivalent (42 Mt CO_2eq). This is needed to be able to reach the EU's overall target for the land sector of 310 Mt CO_2eq by 2030.

This chapter describes the concept of carbon farming, gives an overview of carbon farming options including their climate mitigation potential, discusses carbon farming as a business model, describes the cost, and funding options for carbon farming and finally describes carbon farming in the context of key (EU) policy areas and specifically for Ireland.

2.1 What is Carbon Farming?

Many different definitions for carbon farming exist. A recent definition by COWI (2021[3]): "Carbon farming refers to the management of carbon pools, flows and GHG fluxes at farm level, with the purpose of mitigating climate change. This involves the management of both land and livestock, all pools of carbon in soils, materials and vegetation, plus fluxes of carbon dioxide (CO_2) and methane (CH_4), as well as nitrous oxide (N_2O) (which is included among relevant fluxes of GHGs in the agricultural sector by the Intergovernmental Panel on Climate Change (IPCC) and therefore is considered part of carbon farming)."

The term carbon farming is also often used to refer to a new business model for farmers, which consists of incentives to take up farming practices that deliver a climate benefit at farm level. These incentives can come from public funds, private payments, or a combination of the two. The European Commission's definition of carbon farming as set out in its Communication on Sustainable Carbon Cycles[4] is as follows:

3 COWI, Ecologic Institute and IEEP (2021): Annexes to Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU. Report to the European Commission, DG Climate Action on Contract No. CLIMA/C.3/ETU/2018/007. COWI, Kongens Lyngby.

4 COM (2021) 800 final Brussels, 15.12.2021: https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles_en

"Carbon farming can be defined as a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall."

In all definitions the first priority for carbon farming must be **to avoid future emissions by maintaining management of existing carbon stocks (maintain)**, especially those drained peat-rich soils, wetlands, trees and other woody features; the second is to **reduce emissions that cannot be avoided (reduce)** in routine farm and forest management; the third is **to create new, long-term carbon stores (remove).** Recent studies show that the implementation of carbon farming practices offers an estimated emission reduction and carbon removal potential of 101-444 Mt CO_2-e per year in the EU (Scheid, 2023[5]).

All farms have some potential to deliver carbon farming, the extent varies with the farming system, soils, climatic conditions, and the economic viability of the business. Carbon farming practices can foster long-term resilience to climate change, and also provide soil protection, water retention, shelter for livestock and crops and diversification of income. The three elements mentioned above (maintain, reduce, remove) all should be included in an integrated farm approach. Therefore, a carbon farming package helps reduce GHG emissions, and delivers on-farm climate mitigation, including those that address other greenhouse gases (methane, nitrous oxide) and take account of all emissions and removals over the whole farm. As a result, the definition of the system boundaries is an important aspect of carbon farming.

Figure 2.1 provides an overview of the different system boundaries that can be considered.[6]

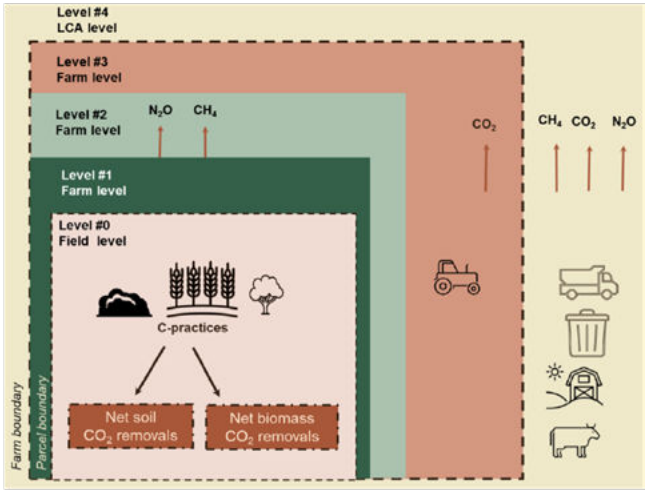


Figure 2.1 Possible system boundaries to be considered before initiating a carbon farming initiative (van der Kolk, in prep.)

5 Carbon farming co-benefits: Approaches to enhance and safeguard biodiversity, 2023: https://www.ecologic.eu/19040

6 Van der Kolk, et al., in prep. Glossary for the development of carbon farming projects, WENR report. Product of the PPS carbon farming

Level 0	at field level includes the soil CO2 removals and the biomass CO2 removals that are achieved during a specified duration in the fields where the carbon practices are applied. This level does not include GHG emissions that may be produced because of the carbon practices, or other GHG emissions produced at farm level.
Level 1	at farm level implies that in 100% of the fields in the farm carbon practices are applied and includes the soil CO2 removals and the biomass CO2 removals. It does not include other GHG emissions produced as a consequence of the carbon practices. It includes all fields on a farm.
Level 2	at farm level, involves CO2 removals, CO2 emissions and non-CO2 GHG emissions coming from C practices at the entire farm.
Level 3	at farm level, involves level#2 plus CO2 emissions from additional actions needed to perform the measures.
Level 4	at Life Cycle Analysis (LCA) level; Involves CO2 removals and all GHG emissions included in LCA and for other emissions that are not directly related with the C practice.
All levels except level 4	include emissions that are directly related with C practices, and the process of carbon sequestration.

Note that there is a difference between gross and net carbon sequestration. Gross soil carbon sequestration is the amount of carbon that increases in the soil as a result of a carbon practice. Net carbon sequestration (in CO2-eq) is the sum between the amount of carbon that is sequestered in the soil and the CO2 emissions (level 1), and the non CO2 -GHG emissions (level 2 and 3) as a result of the carbon practice applied.

$$\text{Net Carbon Seq (level 1)} = \text{Increase in SOC stock} - CO_2 \text{ emissions}$$

$$\text{Net Carbon Seq (level 2, 3)} = \text{Increase in SOC stock} - (CO_2 + N_20 + CH_4 \text{ emissions})$$

For most farms, carbon farming methods are planned and decided prior to making any operational commitments. Selection of activities boils down to baseline field conditions and understanding the goals of the farmer. Monitoring data for accurate accounting of long-term sequestered carbon is critical when conducting carbon farming practices. Rigorous measurement, reporting, and verification (MRV, see section 2.6) are crucial in generating high-quality carbon credits in farming and will play help generating data at farm level.

Credit : Shutterstock

2.2 Carbon Farming Practices

Carbon farming practices are management practices that are known to sequester carbon and/or reduce GHG emissions. McDonald et al.[7] estimated that carbon farming practices had significant mitigation potential, equivalent to 3-12% of current EU emissions (or 26+% of current EU agricultural emissions). Mc Donald et al. also highlighted that there is a lack of information available at national and regional level on which practices deliver the greatest mitigation potential. Table 2.1 provides an overview made by the European Network of Rural Development (ENRD[8]) of the mitigation potential of the most promising practices, including restoration of drained peatland, agroforestry, afforestation, and the management of arable mineral soils. Clearly, the potential variation is wide because the actual carbon capture depends, at the level of individual parcels of land, on the biophysical conditions (e.g., soils, climate) the current farming system/land use and how easily reversed the practice is. At different scales from region to farm to parcel, the actual mitigation potential of carbon farming depends on how, where and for how long carbon farming is practised.

Carbon practices are farm management practices applied to benefit climate mitigation. Therefore, measures can either include something new (adding extra manure) or exclude action (and abandon something) or modify an action (more precise, change intensity or frequency or timing). There are practices at field level (such as adding compost) or at farm level (such as changing rotation schemes). The best practices in carbon programs call for a routine review of carbon farming methods utilized in a farm

7 McDonald, H., Frelih-Larsen, A., Lóránt, A., Duin, L., Pyndt Andersen, S., Costa, G., and Bradley, H. (2021) Carbon farming – Making agriculture fit for 2030, Study for the committee on Environment, Public Health and Food Safety (ENVI), Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, Luxembourg.

https://www.europarl.europa.eu/RegData/etudes/ STUD/2021/695482/IPOL_STU(2021)695482_EN.pdf

8 https://enrd.ec.europa.eu

to see if a farm is on track to reach intended outcomes, while maintaining a good agricultural production as well. For a more complete overview of the different practices that can be applied we refer to the technical guidance handbook for setting up and implementing carbon farming mechanisms[9].

Here a few of these measures are a bit more elaborated:

Reduced fertilizer application: Chemical inputs reduce the capacity of soils to sequester carbon and can be wasteful when applied in excess. Manufacturing mineral fertilizers requires a high amount of energy inputs and contribute to emit an important share of GHG emissions across the EU. Decreased chemical fertilizer application is a cost-reducing way to optimize the nutrient application for crops and improve soil health. According to some estimations made in the USA, approximately 20-40% of the applied nutrients are lost to water or as GHG[10]. By increasing fertilizer use efficiency, impact can be gained both through the reduction of production of fertilizer and the reduced losses.

Managed grazing: This is a holistic range methodology where cattle is concentrated on specific areas and constantly moved to have the remainder of the area to recover from a short intense grazing period. This methodology has proven to enhance soil health, above and below biodiversity and store carbon in the soil[11]. Grazing cattle is managed so that biodiversity is improved, soil health is improved to increase carbon absorption and minimize manure-related greenhouse gas emissions. This system can also be integrated in a mixed land use option such as grazing and solar fields[12]

Supply of manure and compost: Supply of manure and compost effectively enhances the organic matter content because it decomposes less quickly than fresh crop- and root residues. The additional soil organic matter will improve soil health and improve the soil ecosystem services[13]. Supplying manure and compost will also often decrease the necessity to apply fertiliser.

Reduced tillage: Frequent and heavy tilling increases the rate of carbon dioxide released from the soil. In the process, it also breaks up soil structure which can lead to erosion and less productive croplands. Reduced tillage, which is done at minimum or no-tillage at all can have several benefits:

9 European Commission, Directorate-General for Climate Action, Radley, G., Keenleyside, C., Frelih-Larsen, A., et al., Setting up and implementing result-based carbon farming mechanisms in the EU : technical guidance handbook, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2834/056153

10 United States Environmental Protection Agency. (2001). Managing Agricultural Fertilizer Application to Prevent Contamination of Drinking Water. Source Water Protection Practices Bulletin. Office of Water (4606). EPA 916-F-01-028. July 2001. https://extension.usu.edu/waterquality/files-ou/Agriculture-and-Water-Quality/fertilizer.pdf

11 Gosnell Hannah, Charnley Susan and Stanley Paige 2020Climate change mitigation as a co-benefit of regenerative ranching: insights from Australia and the United StatesInterface Focus.102020002720200027

12 Pang et al, 2019 Agroforest Syst (2019) 93:11–24

13 Novara, A., Pulido, M., Rodrigo-Comino, J., Prima, S.D.I., Smith, P., Gristina, L., Giménez-Morera, A., Terol, E., Salesa, D., Keesstra, S., 2019. Long-term organic farming on a citrus plantation results in soil organic carbon recovery. Geogr. Res. Lett. 45, 271–286. https://doi.org/10.18172/cig.3794

Table 2.1: *Overview of examples of carbon farming practices and their mitigation, * After ENRD[14] who made a compilation-drawing upon Ecologic and IEEP (2022) and other research data, completed by Climate-KIC.*

	Carbon farming actions	Mitigation mechanism	Per hectare mitigation potential (t CO_2-e/ha/yr)*	Opportunities for scaling up in the EU
Peatland restoration	Peatland rewetting, subsequent maintenance and management, paludiculture	Avoided and reduced emissions	3.5 - 29	Drained peatlands, predominantly in northern Member States (MS)
Agroforestry	Creation, restoration, and management of woody features in the landscape	Removal	0.03 – 27	Throughout the Eu, in almost all soil/climatic conditions, selection of species should be adjusted.
Afforestation	Creation of new woodlands and forests on sites that have not been forested within the last 50 years	Removal	2.39 – 5.74	Throughout the EU, in almost all soil/climatic conditions
Maintain & enhance SOC in mineral soils	Cropland and grassland management (permanent and ley)	Removal and reduced emissions	0.5 -7	4/1000 initiative
Catch/cover crops	Crops grown between the harvest of one main crop and the sowing of the next (cover crops can be undersown)	Avoided and reduced emissions	-0.01 – 4.6	Make use of CAP
Hedges and woody margins	planting of hedges and woody margins on field edges	Removal	0.65 – 3.3	Implement as part of landscape architecture, make use of CAP
Conservation of near-natural peatland	Existing wetland/ peatland soils	Avoided emissions	0.7 – 2.85	Existing near-natural peatlands throughout the EU
Arable conversion to grassland	Conversion of arable land to permanent grassland which is no longer cultivated	reduced emissions	0.33 -1.44	Arable conversion to grassland
conservation tillage	Reduced tillage reduces organic matter decomposition and increases carbon sequestration	maintain, reduce and removal	Data range is large	Transform arable land to no-or minimum tillage
Cover cropping	Soil is permanently covered with plants such as legumes or grasses, in order to increase the amount of organic matter in the soil and the amount of carbon	reduce, removal	-0.01 – 4.6	Prohibit bare soils outside of harvesting time
Managed grazing	Grazing cattle is managed so that biodiversity is improved, soil health improved to increase carbon absorption and minimize manure-related greenhouse gas emissions	reduce, removal	up to 1	Especially in rangeland promote high-density grazing techniques[15]
Biochar	Adding this form of charcoal made from agricultural waste and other biomass enhances soil fertility and increase carbon storage	removal	High potential	Include in circular agricultural practices
Precision agriculture	Employing technology, such as GPS and remote sensing, to optimize agricultural methods and enhance resource efficiency	reduce and removal	Depends on emission of replaced technology	big potential in horticulture
Reduced fertilizer application	Reduce chemical inputs improve soil health	avoid, reduce and removal	High potential	healthier soil will need less chemical input for soil fertility
Companion crops and strip cropping	Use two or more crops that help each other or grow in different season, avoid erosion, and effluent of nutrients	avoid, reduce and removal	High potential	CAP, through legislation and healthier soils and crops.

14 ENRD Thematic Group on Carbon Farming - Background document; Analytical overview of carbon farming March 2022

15 https://savory.global/wp-content/uploads/2017/02/about-holistic-planned-grazing.pdf

1) the promotion of soil health by leaving the residue on the field, **2)** the reduction of soil compaction (due to heavy machinery), and with less soil compaction, nutrient use efficiency increases, **3)** increased carbon sequestration by leaving the stubbles on the field, and **4)** overall reduced tillage requires less (fossil based) energy as less passes with the machinery on the field are made[16].

Figure 2.2: *Contrasting soils due to organic agricultural practices with a cover crop (dark soil, approx. 4% soil organic matter content) and chemical farming, no-till treated with herbicides to keep the soil bare (light soil, <0,2% soil organic matter content) in two adjacent citrus orchards in Valencia, Spain13.*

Improved residue management: Another soil-protecting strategy in farming is to leave crop residue in the fields. Covering the soil with mulch, or crop residue materials like straws, enhances soil moisture and fertility while allowing the organic material to interact with microorganisms for healthier soil composition. Improved residue managed has a positive impact on soil biodiversity and therefore also on the overall soil health. Improved residue management has agronomic benefits as it retains soil productivity, recycles nutrients from the soil and stimulates root proliferation and economic benefits like reduced fertiliser use, increased harvest and obviously income through carbon credits.[17]

Eliminating bare fallows and increasing the production of cover crops: Leaving cultivated land to lie idle for a season or more leaves the soil exposed without any protection from heat, wind, rain, and weeds where soil carbon can escape more readily. Instead, sowing nitrogen-fixing crops like clover can help keep the carbon in the ground as well as improve the soil's nitrogen content for the next crop. Cover crops are grown to protect the soil, which is different from the primary crop usually cultivated for food production and economic benefit. Cover crops reduce surface disturbance and work to help capture nutrients to build soil fertility and soil organic carbon[18].

16 Hussain, S. et al. Carbon Sequestration to Avoid Soil Degradation: A Review on the Role of Conservation Tillage. Plants 10, 2001 (2021). https://doi.org/10.3390/plants10102001. https://www.mdpi.com/2223-7747/10/10/2001

17 Witzgall, K., Vidal, A., Schubert, D.I. et al. Particulate organic matter as a functional soil component for persistent soil organic carbon. Nat Commun 12, 4115 (2021). https://doi.org/10.1038/s41467-021-24192-8

18 Porwollik, V., Rolinski, S., Heinke, J., von Bloh, W., Schaphoff, S., Müller, C. (2022). The role of cover crops for cropland soil carbon, nitrogen leaching, and agricultural yields — a global simulation study with LPJmL (V.5.0-tillage-cc). Biogeosciences. Vol. 19, 2022. 3, 957-977. https://bg.copernicus.org/articles/19/957/2022/. doi: 10.5194/bg-19-957-2022

Companion crops and strip cropping: Companion planting increases plant diversity by growing 2 or more crops close together to benefit not just the crops but also the soil. Knowledge of complementary crops is necessary to maximize the growth and production of crops. For example, one crop is sown to protect the primary crop from pests and insects. Strip cropping is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. By cultivating in narrow strips of maximum 3 m wide, optimal benefits can be gained on yield and reduced need for inputs, as strip cropping generally improves water infiltration; retains soil moisture; boosts soil fertility; contributes to nitrogen fixation and controls pests[19].

Agroforestry: Farming with the intentional integration of trees with agriculture is known as agroforestry. Agroforestry practices can help mitigate emissions and store carbon in both soils and trees. Not only does agroforestry provide above-ground benefits in the field but it also provides crucial below-ground benefits. It does this while also enhancing farm productivity, increasing soil protection, improving air and water quality; providing wildlife habitat, and introducing diversified income. A range of types of agroforestry exist which all have their specific benefits, limitations and management systems: i) Silvo-arable agroforestry: the trees and crops are integrated into an agricultural land ii) Silvo-pastoral agroforestry: the integration of trees within a grazing system for livestock; iii) Hedgerows, shelterbelts, and riparian buffer strips: Trees or shrubs are planted around agricultural land to form a protective barrier or to mark territory; iv) Forest farming: crop cultivation within a forest landscape and v) Home gardens: combinations of trees and food production close to homes.[20]

Improved task efficiency & fuel efficiency: Planning and delegating tasks in the farm keep operations running smoothly. Useful tools like a farm management software can keep track of planned and accomplished tasks to minimize duplication and to stay on top of duties. Data-keeping in farm operations also provides valuable insight into how resources are used around the farm. Performing regular maintenance on farm equipment, proper storage, and planning tasks accordingly can help keep fuel use and costs to what is necessary. Energy efficiency in the farm increases productivity while limiting emissions from farming.

2.3 Co-benefits and trade-offs of carbon farming

Carbon farming can deliver co-benefits to farmers and society, yet it also poses risks that require attention. Farming practices that work with natural processes can have benefits for biodiversity, water, soil health, and animal welfare. Farmers can also benefit from productivity improvements, reduced costs, and improved farm resilience. Some carbon farming practices, however, can have negative impacts and

19 https://eos.com/blog/strip-cropping/

20 Kay, S., Rega, C., Moreno, G., den Herder, M., Palma, J., Borek, R., Crous-Duran, J., Freese, D., Giannitsopoulos, M., Graves, A., Jäger, M., Lamersdorf, N., Memedemin, D., Mosquera-Losada, R., Pantera, A., Paracchini, M.L., Paris, P., Roces-Díaz, J., Rolo, V., Rosati, A., Sandor, M., Smith, J., Szerencsits, E., Varga, A., Viaud, V., Wawer, R., Burgess, P., Herzog, F. Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe, Land Use Policy, Volume 83, 2019, pp 581-593, ISSN 0264-8377, https://doi.org/10.1016/j.landusepol.2019.02.025

lead to trade-offs (e.g., for soil health, biodiversity, or animal welfare). To maximise win-wins and avoid trade-offs, carbon farming must be designed with safeguards and incentives that favour actions with multiple benefits.

Table 2.2 summaries the benefits and risks for the carbon farming practices identified as having significant mitigation potential. There could be economic benefits for the business too, as with biodiversity benefits these may take longer to achieve and carry risks in that they depend on commodity (including carbon) markets over a longer time frame than is typical for a farm business.

Table 2.2: Overview of a selection of potential co-benefits and related risks for carbon farming practices
*** According to ENRD[21] who made a compilation drawing upon Ecologic and IEEP (2022) and other research data, completed by Climate-KIC**

	CF actions	Co-benefits for land managers	Societal co benefits	Risks	Safeguards needed
Managing Peatlands	Peatland rewetting	Potential for paludiculture/ income from carbon certifications	Biodiversity, flood regulation, water quality	Increased CH_4 emissions	Resilience to climate change impacts, effect of displacing production
Agroforestry	Creation, restoration & management of woody features in the landscape	Diversification of outputs. Reduced risk of single crop failure	Improved water retention, microclimate, soil health, biodiversity	Non-native species, impact on authentical biodiversity monocultures such as poplar plantations, are poor quality habitats and lead to an overall loss of ecosystem services compared to mixed farmland	No agroforestry on peatland, nature conservation objectives
Afforestation	Creation of new woodland and forests on land in other use (or unused)	Diversifications of outputs, potential for future income for carbon certificates	Improved microclimate, flood risk management, recreation	Displacement of production (on agricultural land), consider fire risk management	No afforestation on peatlands, existing nature conservation
Maintain and enhance SOC on mineral Soils	Cropland and grassland management (permanent and ley)	Improved water holding capacity and workability of soils, productivity	Improved water retention, soil health, biodiversity	Biochar, off farm compost impacts on soil health/ biodiversity	Restriction on biochar and municipal compost

21 ENRD Thematic Group on Carbon Farming - Background document; Analytical overview of carbon farming March 2022

2.4 Carbon farming schemes

A carbon farming scheme is any voluntary agreement in which a farmer or a group of farmers commit themselves to apply carbon farming measures in return for a payment in any form[22]. An activity-based carbon farming scheme provide payments for implementing defined carbon farming measures, independently of the resulting impact of those measures. Proof lies in the implementation of the measure. This is contrary to the result-base carbon farming scheme. Here farmers get paid for reducing net GHG fluxes from their land, whether that is by reducing their GHG emissions or by sequestering and storing carbon in soil or woody elements on their farm. The result-based carbon farming requires a direct link between the results delivered and payments.

Carbon credit is the generic term to assign a value to the reduction of greenhouse gas emissions or an increase in carbon sequestration. A carbon credit can be used by a business or individual to reduce their carbon footprint by investing in an activity that has reduced or sequestered greenhouse gasses at another site[23]. Hence CO_2 reductions at a farm may be quantified and sold as carbon credits, under the condition that the measured and calculated CO_2 reductions are verified and validated.

Roughly two different markets for carbon credits out of carbon farming can be identified: the compliance market and the voluntary market. The compliance markets are created because of any national, regional, and/ or international policy or regulatory requirement. EU Emissions trading system (EU-ETS) is one type of compliance market. Voluntary carbon markets refer to the issuance, buying and selling of carbon credits or carbon certificates on a voluntary basis. The main difference between a compliance market and voluntary market is that in compliance markets industry, entities are obliged to buy carbon credits, while in the voluntary market entities show their interest in climate and environmental integrity of offsets, buying those credits is a gesture of goodwill.

Case study: the Road4Scheme project

The Road4Schemes project had made a differentiation in 3 types of payment; the direct farm payments, the schemes set up by corporate supply chain and the voluntary markets[24] (Figure 2.3). They performed an analysis on 179 European carbon farming schemes. 78 of them had a private funding scheme, 54 had a public funding scheme, and 7 schemes had a mixture between public and private funding schemes. The remaining deprived from an answer regarding the funding origin of the scheme.

22 EJPSOIL Road4Schemes; https://ejpsoil.eu/soil-research/road4schemes
23 https://web.archive.org/web/20100912151614/http://www.epa.vic.gov.au/climate-change/glossary.asp
24 https://esdac.jrc.ec.europa.eu/euso/presentations-2nd-euso-stakeholders-forum

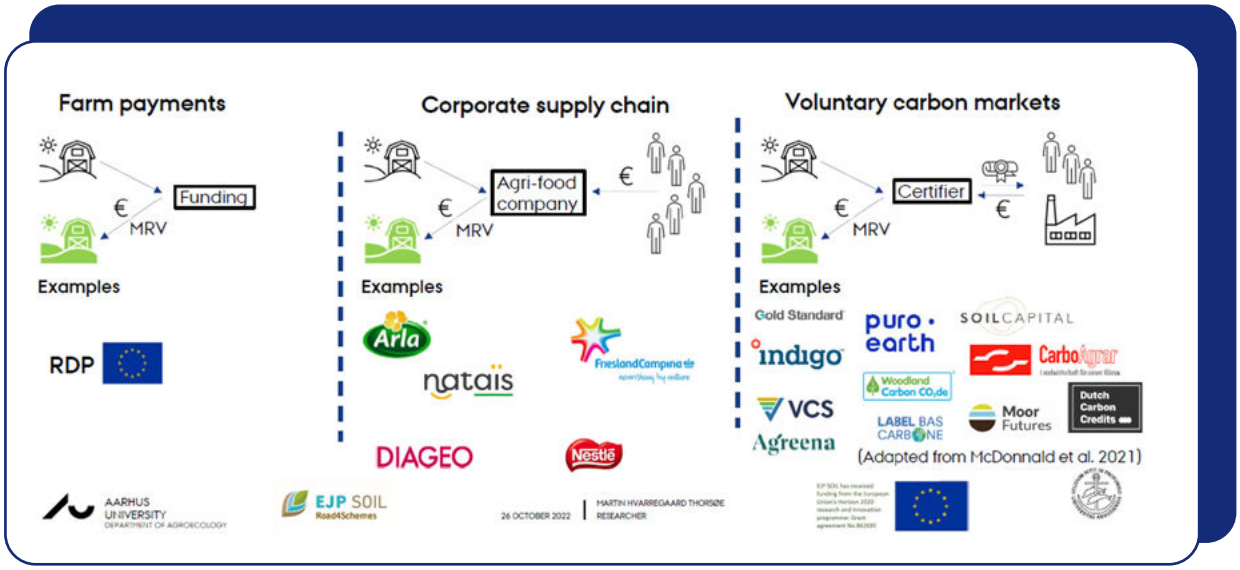


Figure 2.3: *Differentiation of carbon farming schemes according to the Road4Schemes project as presented during the EUSO Stakeholders forum (Thorsøe, 2022)*

Figure 2.4 provides an indication of the land use under the schemes. With 53 schemes, arable framing is the most popular land use to start a carbon farming scheme, closely followed by grassland on peat. In total 80 of the schemes were action-based schemes, 25 were hybrid schemes and 35 schemes were result based. Only 10 schemes worked with carbon credits, yet 80 schemes did make use of a certificate, a label, or another official document.

The Road4scheme project concluded that most carbon farming schemes are found in North-West Europe. And as, is clear from the previous description a plethora of different design options and scales of application exists. The focus of the schemes varies from field to farm, from actions to performance and payment can be gained for either increased carbon storage or for improved ecosystem services.

The opportunities for carbon farming are many. There is a growing market for carbon sequestration and carbon credits. The Road4Schemes team report a growing interest among stakeholders in sustainable land-management and carbon farming, and the co-benefits of carbon farming (see paragraph 2. 3) are an additional incentive on top of the payment schemes.

Yet besides opportunities, many challenges exist. A common monitoring, verification and reporting methods is so far missing, which results in a broad range of approaches for the MRV of carbon. European harmonisation of such a scheme is needed to facilitate a European market of carbon credits. Yet in some countries national schemes are developed to stimulate national

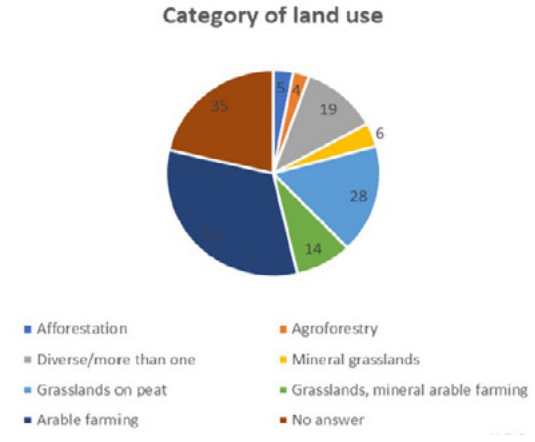


Figure 2.4: *Indication of land-uses under the schemes evaluated in the Road4Schemes project.*

initiatives and a national market (Franch and Netherlands, see section 2.6). Furthermore, there is a need to develop a cost efficient MRV scheme, as the cost of reporting should not surpass the (economic) benefits of carbon farming.

2.5 Monitoring, Reporting, and Verification (MRV)

To ensure that carbon farming actions have positive impact on the climate, it is needed to be able to measure them and be confident that they are occurring. This can be achieved through monitoring, reporting, and verification.

- **Monitoring** refers to measuring the decrease in emissions or the increase in sequestration.
- **Reporting** refers to the processes for communicating these results.
- **Verification** refers to the ability of administrators or other external parties to ensure the truthfulness and accuracy of the results.

Monitoring, Reporting, and Verification (MRV) refers to the multi-step process to measure the amount of greenhouse gas (GHG) emissions reduced by a specific mitigation activity, such as reducing emissions from deforestation and forest degradation, over a period of time and report these findings to an accredited third party. The third party then verifies the report so that the results can be certified, and carbon credits can be issued (Definition by the World Bank).

A good Measurement, Reporting, and Verification (MRV) process is essential to produce verified, responsible emission reduction and credits that buyers can be confident in. However, the process to create this can be complex. A robust MRV is essential to ensure that GHG mitigation and carbon removals start with a **trustworthy baseline**, have **environmental integrity and are real, additional, measurable, permanent, and avoid carbon leakage and double counting**. In this section these elements related to MRV are explained and what each step of the process entails, and technological innovations are needed to transform it.

To be able to assess change in carbon stored in the soil, the first step is to make an inventory of the situation at the start of any project: the **baseline** or reference level against which performance is measured periodically. The baseline of a project is a reference level of the amount of net carbon removals that would have occurred if there would be a continuation of the common practice of not taking additional C-practices to sequester carbon in the soil of the farm. The baseline of soil carbon at farm level is determined by means of a combination of field measurements and robust, scientifically substantiated model calculations.

IPCC[25] and different scientific papers[26],[27] have identified three definitions for environmental integrity that show the relevance of the action of carbon farming:

1. **Aggregate achievement of mitigation targets:** Environmental integrity would be ensured if the engagement in international transfers does not lead to a situation where aggregate actual emissions would exceed the aggregated target level.
2. **No increase in global aggregate emissions:** Environmental integrity would be ensured if the engagement in international transfers leads to aggregated global GHG emissions that are no higher as compared to a situation where the transfers did not take place.
3. **Decrease of global emissions:** Environmental integrity would be ensured if the engagement in international transfers leads to a decrease in global GHG emissions as compared to a situation where the transfers did not take place.

After establishing the baseline it is necessary to ensure **additionality**. This concept states that carbon farming must demonstrate that carbon sequestration on agricultural land is additional to existing agricultural policy or management. That the carbon sequestration that is measured is indeed the result of changed agricultural management practices, such as i) introducing new measures, ii) discontinuing current practices that hinder carbon sequestration, iii) optimizing business operations for carbon sequestration, or a combination of these.

When carbon emissions are reduced on a farm by relocating activities that cause carbon emissions outside of the carbon farming project area, this is referred to as **'leakage'**[28]. Leakage risk can be avoided by strengthening the design of the carbon farming scheme as well actually estimate the leakage that will occur and calculate the emission reductions and removals taking the leakage into account.

In carbon farming a **buffer** is a financial reserve of carbon removals within a carbon farming project that can account for issues with non-permanency. The buffer pool works as follows: when a system has a net sequestration rate of x tons C/ha in a certain year, a part of that is 'set aside' in the buffer to account for potential carbon losses in the future. When a carbon stock is released unexpectedly prematurely, removals can be taken from the buffer pool as a replacement. The size of the buffer pool should obviously be adjusted to the project details as with each project the risk of reversibility will vary.

25 IPCC. (2014). Climate change 2014: Mitigation of climate change. Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, … J. C. Minx, Eds.). Cambridge University Press.

26 Woerdman, E. (2005). Hot air trading under the Kyoto Protocol: An environmental problem or not? European Environmental Law Review, 14(3), 71–77.

27 Schneider, L., La Hoz Theuer, S., 2019. Environmental integrity of international carbon market mechanisms under the Paris Agreement. Clim. Policy 19, 386–400. https://doi.org/10.1080/14693062.2018.1521332

28 McKinsey-Company, 2020: https://www.mckinsey.com/industries/agriculture/our-insights/reducing-agriculture-emissions-through-improved-farming-practices

Permanence in the context of carbon farming can be defined as: "Avoiding the loss of built-up organic matter after contract period (reversibility)". Typically, the organic matter build up over the time frame of the period of the contract is used as the amount that will be paid for. However, this amount of carbon may be lost from the soil afterwards due to oxidation and decomposition.

Methods for monitoring

To be able to evaluate if carbon has actually been stored, it is needed to accurately measure the amount of carbon and monitor this over a certain period of time. To do this fairly it is important that MRV captures all carbon farming impacts on the climate. All elements and impacts of the carbon farming actions are important to be monitored. In case not all GHGs are monitored the total net effect on climate mitigation can be negative due to trade-offs related to the interaction of specific management option with different GHG. Therefore, all these carbon stores must be monitored, CO_2 as well as emissions of nitrous oxide, methane, and carbon dioxide. Monitoring can be done using two complementary methods: direct measurements and modelling. In the section below we explain both approaches with their strengths and weaknesses.

Direct measurement; Direct measurement related to carbon storage in soils and of GHG gases emitted, in the context of carbon farming relates the three elements mentioned before: avoided, reduced and removed (captured) GHG. Different measuring approaches can be applied: direct laboratory approaches as well as proxy measurements, where measuring another aspect of soil gives an approximation of the actual amount of carbon in the soil. The two approaches can be largely grouped into two categories: direct measurements and remote sensing. The direct laboratory measurement can monitor GHG impacts with considerable accuracy but can be prohibitively expensive. Often the cost of analysis compromises the accuracy of measurements when it comes to averaging between the number of measured points and getting a good assessment of the carbon stored in the soils on a farm.

Indirect measurement: Currently innovations in soil carbon analysis are being developed, including proximal and enhanced in-field sensors which can analyze soil without sending it to the lab. Other innovations include novel laboratory-based techniques for analyzing soil cores, which reduce the cost and time required to perform the analyses. Next to innovations in soil carbon measurements remote sensing brings many opportunities for upscaling measurements. Both, proximal sensing (handheld field devices), drone imagery and satellite imagery are promising tools to use. Currently, large research investments are being made to develop methods to assess soil carbon with these remote sensing techniques. But satellite imagery can also map agricultural practices that significantly impact soil carbon sequestration. These practices include tillage, crop rotation, and cover cropping. By using satellite imagery instead of manual labor (people driving to check fields), carbon certification providers can dramatically reduce their costs. This also allows for a standardized method of reporting, which relies on objectively verifiable imagery rather than subjective in-person data collection. Additional new artifi-

cial intelligence methodologies are rapidly being developed. These methodologies can be a real game changer if they are able to assess the amount of carbon stored per x unit of land based on available or easy and cheaply acquired data.

Modelling: Next to direct or indirect measurements it is also possible to model GHG emissions and removals. These estimations are based on a combination of measurable proxy data and already-known scientific relationships. Modelling requires previous scientific research to establish relationships between proxies and estimated emissions/sequestration. Modelling has higher uncertainty than direct measurement but lower costs. In addition to scaling actual measurements, modelling can also be used for scenario planning, meaning that a farmer can estimate how much profit a practice would bring before making the practice change. Obviously, a certain amount of soil testing will always be necessary to calibrate and validate suitable soil models. However, once the model is calibrated and validated for use in a specific geography and with a set of farming practices, it can be used for planning purposes with limited resampling. It is important to realize that the amount of specific data used in the calibration (and validation) will determine the accuracy and uncertainty of the estimates that it provides.

Costs and uncertainties: For each element of the carbon balance on a farm similar monitoring and evaluation problems are faced related to accuracy and scalability. Table 2.3, provides and overview of different monitoring approaches that are commonly applied to monitor farm-level carbon farming in the different carbon farming sub-categories. The accuracy and costs varies per methodology, depending on inherent challenges in the different carbon farming options, and due to different MRV methods and technologies used for MRV. It is expected that new models and algorithms will improve and more data will come available, making the MRV methods more reliable and useable across different scales.

Table 2.3: *examples of costs and uncertainty of different MRV approaches in carbon farming sub-categories*[29]

Carbon farming options	Type of monitoring	Uncertainty	Costs
Managing peatlands	Modelling	Medium	Medium
	Measurement	Low-medium	Very high
Soil carbon on mineral soils	Modelling	High	Medium
	Measurement	Medium	Very high
Agroforestry	Combined (modelling + measurement)	High	High
Livestock + manure management	Modelling	Medium	Low-Medium

29 Based on COWI, Ecologic Institute and IEEP, 2021b; own elaboration

Reporting and Verification

Good quality reporting and verification entails the implementation of secure registries, long-term reporting obligations and random and targeted auditing. Reporting and verification processes are especially important if carbon farming is used to generate offset credits that will be used by other sectors in stead of reducing their own emissions. Without robust reporting and verification there is significant risk that carbon farming mitigation could be low-quality. Eventually a lack of trust in carbon certificates may reduce its value (see chapter 8).

A robust MRV system should comprise of an (preferably open source) platform that supports capturing emissions, emission reductions and finance received by each mitigation activity and tracks these at individual project, sector and national level.

The reporting works as follows:

- A program of measures is agreed and implemented;
- A baseline is measure at the start of the project;
- Data is collected and compared to the baseline;
- Emission reductions are calculated over the monitoring period;
- A report is compiled that is then subject to third-party verification by an entity accredited per the requirements of the standard being used.
- After verifying the emission reduction, the standard-setter certifies them, signalling the applicable emission reduction transaction registry to issue carbon credits (ERCs).
- To secure the process random and targeted auditing is implemented in the registry systems, and long-term reporting obligations are in place.

For the success of carbon farming a robust MRV is essential, but cost and scalability have been raised as threats to a successful implementation this over large areas.

The costs: it can be expensive to accurately measure and validate the GHG impact of carbon farming. This causes a trade-off between MRV accuracy and cost. High MRV costs (financial or time) decrease the net-benefit of carbon farming and can act as a significant barrier to farmers voluntarily implementing carbon farming actions or to administrators establishing policies.

Scalability: a low number of data points may reduce the reliability of the actual carbon emission reduction/sequestration. Models used may not be accurately performing with low data inputs. This threat may as more fields are enrolled in carbon programs, and as more data is collected on field practices, the uncertainty of the modeling is reduced.

2.6 Carbon farming at EU level

The European Union has paid a growing attention to the role of carbon sinks. The European Climate Law emphasises the contribution of the agriculture, forestry and land use sectors in the transition to climate neutrality in the Union. That's why the European Commission had proposed as part of its overarching European Green Deal agenda to come up with a carbon farming initiative as well as a regulatory framework for certification of carbon removals based on a robust and transparent accounting.

The Common Agricultural Policy (CAP) remains the most important policy framework and funding programme for the agriculture sector in the EU. The new CAP that started on 1st January 2023 will play an important role in supporting and upscaling carbon farming practices, especially through eco-schemes and agri-environmental and climate measures that are described in Member States Strategic plans, all approved by the European Commission.

In 2021, the European Commission also put forward a proposal to revise the land use, land use change and forestry (LULUCF) regulation as part of the 'Fit for 55' package. The new adopted regulation sets a new ambitious EU target of 310 Mt CO_2e of net removals in the LULUCF sector in 2030. The EU aims to progressively increase absorptions while reducing emissions after 2030 and reaching climate neutrality in the combined land use, forestry and agriculture sector by 2035.

An EU initiative on carbon farming

The Commission's Communication on Sustainable Carbon Cycles published in December 2021 stresses the importance of enabling a business model that rewards land managers for carbon sequestration in full respect of ecological principles and of creating an EU internal market for capture, use, storage and transport of CO^2 through innovative technologies. The EU acknowledges the significant role of carbon farming to play in contributing to resilience and biodiversity goals as well as providing a new source of income for land managers who could benefit from a more fertile and resilient land. The Commission's proposal aims to address barriers that may prevent carbon farming practices to be scaled up while ensuring that adequate reward for the carbon credits generated. Several key actions have been put forward in the Commission's proposal to support carbon farming:

- create an expert group on carbon farming where Member State authorities and stakeholders can share their experiences in view of establishing best practices on carbon farming and on robust monitoring, reporting and verification;
- provide guidance and mainstream dedicated carbon farming funding in most relevant EU policies and related tools (such as the Common Agricultural Policy, LIFE, Cohesions funds) to contribute to address the relevant implementation challenges;
- support the coordination of the research community and key stakeholders on developing, testing and demonstrating carbon farming practices through Horizon Europe clusters 5 and 6;
- provide a digital carbon navigator template and guidelines on common pathways for the quantitative calculation of GHG emissions and removals for agricultural land managers;

- carry out a study to assess the potential to apply the polluter-pays principle to emissions from agricultural activities;
- create a carbon farming group within the Climate Pact social platform to bring together land managers to encourage them to become Climate Pact ambassadors and feed the exchange on direct experiences;
- create living labs that test and demonstrate practices for carbon farming across various locations in Europe under the mission "A Soil Deal for Europe";
- promote and pilot blue carbon farming practices through some of the lighthouses of the Mission "Restore our Ocean and Waters".

An EU certification framework for carbon removals

A major barrier to the upscaling of carbon removals is the lack of a common EU standard for the transparent identification of activities that remove carbon from the atmosphere in a sustainable way. Existing public and private schemes, such as in voluntary carbon markets, certify carbon farming practices but apply a wide variety of approaches to quantify their climate benefits. To address this inconsistency, the European Commission has recently presented a proposal for a regulation on 'establishing a Union certification framework for carbon removals'[30]. This initiative aims to develop a voluntary EU certification framework for carbon removals to ensure the uptake of high-quality removals and improve the EU's capacity to quantify, monitor and verify carbon removals in a reliable and harmonised way across the EU. In the case of carbon farming, such certification framework will also encourage the uptake of carbon removal activities that generate co-benefits for biodiversity and contribute to nature restoration targets.

To this end, this initiative proposes a certification framework based on four quality criteria (so-called QU.A.L.ITY) which will ensure i) quantification, ii) additionality and baselines, iii) long-term storage and iv) sustainability of carbon removals. These criteria are defined in Chapter 2 of the proposed regulation.

In a second step, certification methodologies to implement the QU.A.L.ITY criteria across the different carbon removal activities will be developed by the European Commission supported by experts. The first meeting of the expert group is planned for the first quarter of 2023. The Commission's proposal is currently (February 2023) under discussion by both the European Parliament and Member States. Therefore, the proposal might continue to evolve especially since it has left many pending questions according to stakeholders.

The measures that lead to organic matter build-up are carried out during the contract period. Strictly speaking, this means that there is no guarantee that the CO_2 captured during the contract period will not disappear after the contract has ended. This risk is limited if motivated farmers are selected who regard this as an additional revenue model. A letter of intent must be included in the contract to continue sustainable soil management on the farms after the end of the contract period."

30 https://climate.ec.europa.eu/document/fad4a049-ff98-476f-b626-b46c6afdded3_en

2.7 Examples of Carbon farming schemes across Europe

In this section we first present a EU wide assessment of carbon farming in the LIFE project. Secondly, three national examples of carbon farming schemes in Europe are presented, a case in France, in the Netherlands and in the UK.

LIFE Carbon Farming project: farmers knowledge and needs

To test the newly developed scheme the LIFE Carbon Farming project studied and piloted carbon credit supply and demand to support the development of European climate policy and regulation. The objective of the project was to explore and suggest mechanisms for incentivising carbon farming and carbon forestry in order to increase carbon sinks by taking both public and private funding options into consideration. The project sought attractive and realistic solutions that are verifiable and cost efficient as well. With the ambition to find tangible and practical means which respond to different stakeholders' needs the LIFE project explored the current obstacles to a functioning and realistic carbon credit market market, and explored farmers interests and needs across Europe.

As current obstacles for a realistic market the projects reports mention: i) Lack of regulation and guidelines on the national and EU levels ii) Lack of knowledge on producers, market users, and other actors and iii) No realistic and workable market model currently exist. These barriers would need to be overcome to assure a good market.

Permanence and preferred contract length

In the project the permanence of the mitigation benefits were found to be crucial to achieving EU targets for the land-based sector. However, it also affects how secure a carbon farming business model is for the land manager and therefore the funding options, both public and private, that will be most likely to support the upscaling required to deliver the demanding EU target for a climate-neutral land sector and maintain this in perpetuity.

Simulations concluded that all carbon farming practices sequester the highest volume of carbon within the first 10 years after introduction. However, the farmers' survey and interviews found out that the optimal contract length for farmers is between five and 10 years. In other words, farmers are not keen to make commitments longer than five years. Vis-à-vis this anticipated permanence, farmers are obliged to react rapidly to changes in their operating environment, the cultivated species, the weather, and the crop market. As a result, for a farmer, a ten-year commitment is an exceedingly long one.

Participating in a scheme

It would be recommended that joining the scheme is easy and without extra bureaucracy for farmers. There is also a vast need for more shared knowledge around carbon farming. Within the pilots that have run in 16 countries, over 80% of participant farmers preferred to be involved and represented jointly through a central body. This preference indicates that the administrative burden of monitoring, verification, and third-party validation may be a barrier for individual small or medium-scale farming and forestry businesses. The primary concern of farmers is the viability of their agricultural business. For arable farming soil to be productive, resilience to extreme weather and reduced costs of external inputs are vital to profitability. The benefits of climate and soil health were more important to farmers than earnings from potential carbon trading. Nevertheless, farmers aspire for regular yearly income.

The French Label Bas Carbone; A voluntary certification framework

The French government launched a voluntary carbon certification framework in 2019 called 'Low carbon label' (Label bas carbone). The tool is a key measure to address climate change mitigation and will contribute to the targets outlined in the French Low Carbon Strategy.

The objective of the label is twofold:

- Promoting the emergence of local actions that contribute to climate mitigation efforts and can help disseminate good practices;
- Mobilising innovative financing for climate action from a wide range of stakeholders.

The label is a certification tool which guarantees that projects actively contribute to GHG emissions reduction and to carbon sequestration in a transparent manner and in compliance with reliable and verified methodologies.

The framework provides funding opportunities to local projects which support additional climate mitigation efforts while providing opportunities for companies, public authorities or individuals to offset their GHG emissions. However, this scheme cannot be used to compensate carbon emissions in the scope of regulatory obligations such as the European Trading System (EU ETS).

There have been 357 projects in France benefiting from the low carbon label so far, representing an estimated impact of 1.4MT CO_2e. France wants to further develop this type of certification scheme to help amplify the contribution from the agri-forestry in the pathway towards climate neutrality.

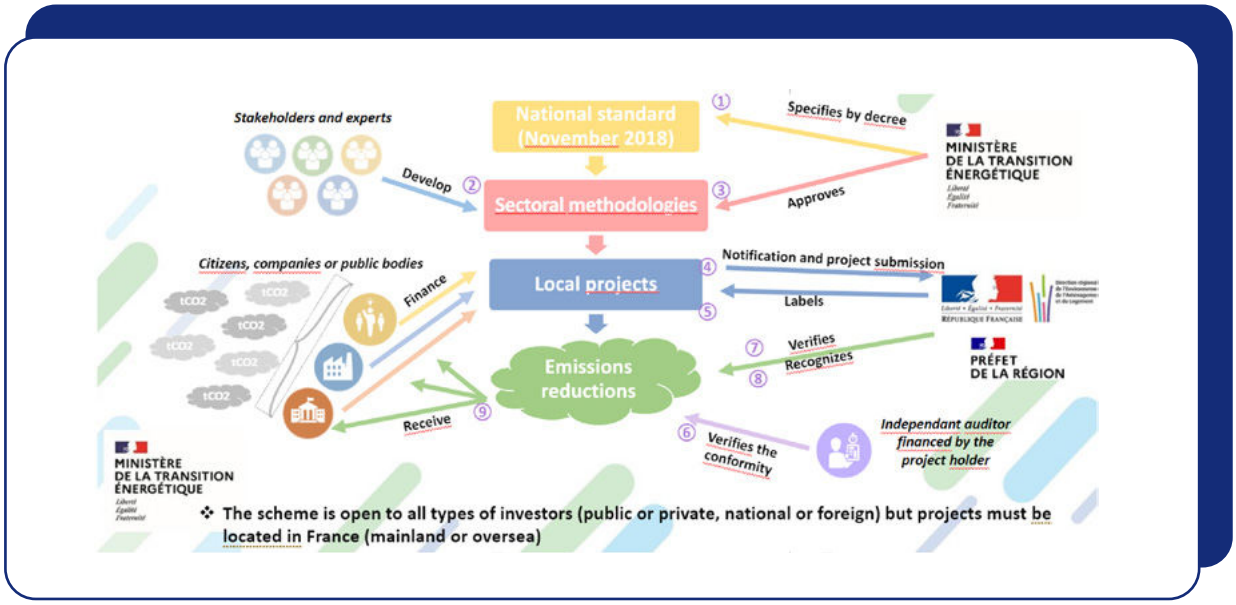


Figure 2.5: *Functioning process of the low carbon scheme (Source: Ministère de la transition énergétique).*

How does it work?

Figure 2.5 summarizes the process of development of the certification scheme which is based on four main steps:

4. The launch of a national standard ('label bas carbone') developed and validated by the Ministry for the Energy Transition;
5. Development of sectoral carbon certification methodologies with the support of specific stakeholders and experts, then approved by the Ministry;
6. Project holders can then apply, on a voluntary basis, for a certification. Projects will be assessed to determine whether they comply or not with the relevant sectoral methodology. Regional authorities review and approve applications. Once projects are certified, investors will be guaranteed to fund activities which demonstrate a positive climate impact.
7. Emission reductions are monitored accurately and verified by an independent and qualified auditor, according to modalities specified in the method, in which additionality is a key criterion.

Additionality is compared to a baseline scenario determined in the methodology which takes into account, for example a similar situation in the absence of labelling, regulatory requirements and common practices, incentives provided by other instruments. Therefore, only emissions reductions that go beyond the baseline scenario are recognised.

The low carbon standard relies on the development of sectoral methodologies that are developed by relevant stakeholders and experts and approved by the Ministry. Each methodology must:

- Specify eligibility criteria of the projects;
- Specify how additionality is demonstrated;
- Evaluate the co-benefits (negative and positive impacts);
- Take into account the risk of non-permanence and of release of carbon, by applying discounts;
- Determine the procedures to verify the emissions reductions;
- Specify the procedures to monitor the indicators.

So far a set of 11 methodologies have been approved so far (afforestation, reforestation, orchard plantation, sustainable hedge management, livestock-crop farming, adapted input management, cattle feeding, and fieldcrops). The label has expanded beyond agriculture by approving the use and reuse of local workspaces and building materials. Other carbon emissions reduction and sequestration methodologies are currently under development such as pig farming, agroforestry, winegrowing, forestry with continuous cover or improved protection of wetlands.

A specific initiative has been set up for farmers to give them the opportunity to assess the carbon emissions generated by their farm and further incentivize carbon farming practices. For example, farmers established for less than five years can benefit from a tool called the "Good Carbon Diagnosis" which carries out a carbon diagnosis of farms accompanied by a report allowing farmers to identify the measures which could have a positive climate impact. The initiative is subsidised up to 90%. The farmer will only have to contribute up to 10% of the total cost, i.e. a contribution of around €250. Based on this assessment, an action plan is defined to develop agricultural practices that promote the reduction or storage of greenhouse gases according to the levers identified by the methodologies of the Low-Carbon Label. With the right carbon diagnosis, the Government encourages young farmers, from the first years of activity, to develop agro-ecological approaches which can contribute to meet the national emissions reduction targets.

Financing

The framework has attracted a growing number of funders in the last four years, either private or public entities which are often interested to voluntarily compensate their carbon emissions. The financing of projects under the low-carbon label and the allocation of the associated emission reductions correspond to the compensation of the operator's emissions or its voluntary contribution to climate change mitigation.

There is no specific scheme in place to connect funders with project holders. The connections are intended to be set up individually or through intermediaries that may use the Low Carbon Label official webpage also offers a platform where both funders and projects are listed. Once the connection is established, there are several financing options which are defined within a contract signed between the funder(s) and the project leader to arrange the payment scheme and timing. There is no fixed cost in €/tCO_2e set under the Low Carbon Label (the government). The price and moment of payment is decided by mutual agreement between the project leader and the funder(s). As an indication the government suggested a payment of 8-125€/tCO_2e with an average of €35 according to projects that have been certified so far.

Perception and criticisms

Four years after the creation of the voluntary certification framework, the French government has expressed a willingness to further develop the certification framework following the first positive results. So far, most of the projects funded in the scope of the scheme relate to the agricultural and forestry sectors. The 'label bas carbone' has been generally positively welcomed by stakeholders and seen as an interesting tool to address climate change mitigation, even though some limits and shortcomings have been observed. First of all, according to a coalition of NGOs, the scheme diverted from its original purpose (funding positive environmental projects at local level) to be used by companies as an offsetting instrument. Secondly, the standard does not differentiate between emissions reduction and sequestration This makes it difficult to evaluate how much carbon can be stored following the implementation of certified projects and whether carbon removals will be permanent or not. Therefore, the carbon certification standard may only be one instruments amongst other policies and measures to lead transformational change in the land agri-food sector. Furthermore, it was recommended to improve the standard to guarantee it can have co-benefits for biodiversity and human and animal welfare and will reward systemic change to agricultural practices.

The case of the Netherlands Organising the National Voluntary Carbon market

Certification

Setting up a national carbon market has a long history", according to Hans Warmhoven, director of the National Carbon Market Foundation. "In 1997, the Kyoto climate protocol was created to reduce greenhouse gas emissions. One of the measures was to set up an international emissions trading system. In Europe, by extension, the ETS was created, which includes energy and industrial companies. Sectors such as the built environment, agriculture, nature management and transport do not participate in the ETS. As a result, CO_2-reducing projects in these sectors are more difficult to get off the ground if the government does not have a policy for them. With a national carbon market, this potential can be exploited. The idea is that project developers set up projects and that companies can invest in them

through certificates. They do this because they want to offset their CO_2 emissions through Dutch climate projects. It is necessary to set up a national standard so that you as an investor have certainty of the value of the certificate. This standard was developed in the Green Deal National Carbon Market

The National Carbon Market Foundation (SNK)[31] emerged from the Green Deal National Carbon Market and supports a market instrument that assigns financial value to project-based emission reductions. The emission reduction is determined in tradable certificates. Possible buyers are parties who want to (voluntarily) invest in the climate and thus contribute to mitigating climate change. The SNK supports local projects and climate actions in all kinds of sectors and stimulates knowledge about and support for CO_2 reduction.

The National Carbon Market Foundation guarantees the quality of the carbon certificates, so that the market can be confident that the emission reduction or carbon sequestration stated on the certificate has actually been achieved. SNK has established a set of methods for calculating emission reductions for different project types (the 'Rulebook'). Project parties use these methods when drawing up a project plan that is validated by SNK. Projects with a validated project plan can start and reduce emissions. The achieved emission reduction is verified by independent experts. SNK issues certificates to the project parties for verified reductions.

Albelli, nationally and internationally known for its photo products for consumers, committed to more sustainability. The organization is actively working on a lower carbon footprint. For the part that is not yet successful, bonusprint opts for voluntary compensation and therefore invests in achieving a CO_2 neutral footprint.

A recent example of this is Valuta voor Veen, where CO_2 certificates were purchased from organic farmer Sjoerd Miedema. By raising the water level in his peat meadows, he ensures less CO_2 emissions from the peat. He receives a certificate for every ton of avoided emissions. The purchase rewards the Frisian peat meadow farmer for his social efforts and Albelli makes a positive contribution to climate, landscape, nature and agriculture. The match was made by the Platformco2neutral.

Matching Supply and demand

There are many, and a continuously growing number of methods available and approved that capture carbon. Choosing which methods to apply under which circumstances to assure additionality requires expertise that a landowner willing to start with carbon farming not always have. Setting up a project costs time and requires insight in the complexity. Furthermore, a matchmaking needs to arise between parties providing and parties paying for carbon credits. The Platform C02neutral[32] is an initiative of the

31 https://nationaleco2markt.nl/
32 https://platformco2neutraal.nl/

Dutch Nature and Environmental Federation. It is a non-profit platform that brings together supply and demand of certificates for the voluntary national carbon market. These are certificates that arise from nature-based projects with which CO_2 emissions can be prevented, recorded or reduced. The platform itself does not develop projects. The providers do this themselves, with the support of the environmental federations, regional government or others. The Platformco2neutral provides the link between landowners and the relevant nature and environmental federations in the provinces or other advisors.

The non-profit platform encourages landowners to get started with CO 2 reduction and sequestration with natural solutions (soil, forest, peat), including the Valuta voor Veen water level raising method. Application of these methods leads to the issue of tradable CO 2 certificates. The platform provides a place where certificates are made available to citizens, companies and governments who want to compensate for their CO_2 emissions. Furthermore, takes care of the transactions between buyers and sellers. By having the projects checked against the methods determined by the National Carbon Market Foundation.

The UK case: The Peat Code

The Peatland Code is a voluntary certification standard for UK peatland projects wishing to market the climate benefits of peatland restoration and provides assurances to voluntary carbon market buyers that the climate benefits being sold are real, quantifiable, additional and permanent.

The Peatland Codesets out a series of best practice requirements including a standard method for quantification of GHG benefit. Independent validation to this standard provides assurance and clarity for buyers with regards the quantity, quality of emissions reductions purchased. Recognising that carbon benefits arise for many years after the initial restoration activities are implemented, the Peatland Code also ensures the carbon benefit will be regularly measured and monitored over the lifetime of the project (minimum 30 years). Buyers can therefore be confident in purchasing peatland carbon units upfront, enabling the restoration project to take place. Funding obtained from the sale of climate benefit can sit alongside traditional public sources of funding, providing cost effective peatland restoration and ensuring management and maintenance of restoration projects over the long term.

The Peatland Code is currently designed to attract private purchases motivated by corporate social responsibility. The funding received from the sale of carbon benefit will depend on the extent of damage prior to restoration, the size of the project and the length of the management agreement. The wider associated ecosystem service benefits of restoration (improvement in biodiversity, cleaner water, water flow management) may also become a unique selling point of the project.


shutterstock_537817624.jpg

The Peatland Code works for everyone involved: Carbon buyers have reassurance that they have facilitated a responsible scheme, which will result in additional climate benefits

- Projects have recognised procedures and standards to work to, and can use their validated/verified status as a means to market the carbon benefits to potential buyers
- Society will benefit from enhanced climate mitigation and the restoration of the natural landscape

July 2022; The Peatland Code has seen recent rapid growth, all registered projects are now predicted to deliver 3,194,681 tonnes of CO2e emissions reductions over their project lifetimes. These projects are securing 14,471ha of peatland restoration in Scotland, England, and Wales. In 2022 alone, 36 projects have already been registered with many more under development. The 100th project to be registered under the Code is Mar Estate (Cran Creagach) in Aberdeenshire, Scotland.

A UK case Creditnature

https://creditnature.com/

CreditNature is a UK firm that has developed a platform that brings together landowners and investors to work together to regenerate ecosystems. They offer three distinct services:

1. **Natural Asset Investment Recovery Analytics (NAIRA)**

This contains a suite of metrics that measure ecosystem 'integrity' (processes and resilience) which can be converted into a single score to track nature recovery progress. This is underpinned by an 'Ecosystem Management Rating' that assesses the impact of current and future land management practices on ecosystem integrity. A scale of A-G is used , which aligns well with the broadly known energy rating for a building or appliance. Key attributes include:

i. Offers direct and affordable measures of change, based on the latest ecosystem science
ii. Can be linked directly to biodiversity and carbon metrics
iii. Designed to give investment-grade asset level data
iv. Scalable, comparable across terrestrial geographies and cost-effective at scale
v. Upgradable as technologies and techniques improve.

2. **Nature Impact Tokens**

These are digital assets that represent a fractional stake in a nature recovery project. The tokens connect investors with like-minded land owners to deliver investable nature recovery projects for the benefits of nature, people and business. The tokens are developed and verified using NAIRA ((Natural Asset Recovery Investment Analytics). Tailor made editions and collections of tokens can also be created (minted) to allow the flexibility to either invest in a fraction of a nature recovery project, a full project or a portfolio of projects.

3. **Nature Positive Carbon**

The NARIA (Natural Asset Recovery Investment Analytics) framework and Nature Impact Tokens can be linked to carbon to produce a premium 'nature positive' carbon credit.

Nature credit has baselined around 20,000 hectares of land so far in the U.K (March 2023). The idea is funders effectively fund such interventions in land restoration. This gives them rights to carbon credits and or ecosystem credits (nascent market).

2.8 Recommendations to set up carbon farming in Ireland

Ireland's Climate Action Plan 2023 recognises that carbon farming can play a central role in encouraging the changes necessary to reduce greenhouse gas (GHG) emissions and to support additional environmental benefits. An enabling carbon framework is due to be developed by Q4 2023. Here it may be interesting to closely follow what is going on in Europe, in order to assure the national framework is in line with the European framework, which may greatly in enhance long term success of the developments of the national carbon market. Furthermore, we strongly advice to develop a flexible framework, that allows adoption of new insights, methods and financing mechanisms as a lot of research is currently going on, which may enrich the Irish framework in development.

Here we provide recommendations for considering in the development of the Irish carbon farming framework and market:

- It is important to set up a long-term carbon farming scheme, to secure farmers of their future income.
- Carbon farming starts with a good baseline assessment as this is essential for a successful carbon farming scheme.
- Based upon the local situation, a good carbon farming plan needs to be developed; good independent advice is required; one can explore options of training carbon farmer advisors to develop the plans and the make sure that the agricultural sector becomes aware of the opportunities (and the risks) carbon farming may provide.
- A trusted certification organisation needs to be set up that works according to the agreed standards; following the Dutch and French examples, the ministries of agriculture have a role to play in these organisations.
- The certification organisation needs to approve the carbon farming plans and explore the mitigation potential.
- A range of MRV methodologies and approaches are available to demonstrate the effect of carbon farming practices. It is necessary to set up a(n inter)national standard so that you as an investor have certainty of the value of the certificate. A good balance between administrative burden and costs for MRV is required to assure farmer participation. Therefore it remains interesting to explore the use of remote sensing to reduce costs from on-the-ground measurements and the potential of artificial Intelligence (AI) models in MRV.
- Once certificates are available, there is e need to provide matchmaking between certificate holders and interested buyer. These matchmakers need to explore the integrity of the buying organisation, in order to avoid the continuation of unsustainable practices within that organisation
- A locally adapted governance for carbon farming can support scaling of carbon farming through cooperation within the supply chain and addresses the need for regional based strategies for carbon farming.

Finally, we want to recommend exploring broader opportunities beyond payment for carbon farming. The inclusion of biodiversity in a carbon farming scheme may provide an opportunity to tackle 2 large societal challenges in one go; the climate crisis and the risk of biodiversity collapse.

3. Proteins & Feed

Authors:

Steve Evans | Karen Lawrence

Credit: Shuttershock

Acknowledgements

Project X would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Steve Evans and Karen Lawrence

Reviewers

Marcella Navaro (Project X) Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC), Saskia Visser

How to cite this Chapter:

Project X (2023). Proteins & Feed. Chapter 3 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Glossary

Alternative proteins	Food that is high in protein that you eat instead of meat and seafood. This includes plant proteins such as soy, hemp seed and ancient grains such as quinoa. It also includes emerging products such as edible insects and lab grown meat.
Anaerobic digestion (AD)	A form of waste processing whereby organic matter, such as animal, food or other materials, is broken down, or digested, to produce biogas and biofertiliser. Considered a form of 'recycling' within the food and drink material hierarchy.
Animal by-products (ABP)	Entire bodies or parts of animals, products of animal origin or other products obtained from animals, which are not intended for human consumption.
Animal protein	Protein derived from meat and/or seafood intended for human consumption. This includes whole animal protein (e.g., chicken breast), processed protein (e.g., chicken pieces present in a ready meal) and products derived from animals (e.g., milk and eggs).
Anti-nutritional properties or factors	Molecules that reduce the absorption of nutrients or proteins in the gut. It's a defence mechanism common in seeds
Aquafeed	Feed substance used in the aquaculture industry, usually a compound feed with a scientifically balanced nutritional content
Bio-economy	Any economic activity involving the use of bio-technology or biomass in the production of goods or services or energy
By-product	An incidental or secondary product resulting from the manufacture or synthesis of something else
Cerrrado	Large area of savannah grassland in Brazil
Chitin	A substance found in the exoskeletons of insects, other arthropods and in fungi. Chitin is used in a range of industrial processes, including the production of pharmaceuticals, food and cosmetics.
Carbon Footprint (CF)	Measure of the GHG emissions in CO_2 equivalent kilos as a way of standardising the overall climate impact a product or animal is having.
Compound feed	Mixture of balanced feed ingredients that are commercialised and held together by oils and sold in pellet form
Crude Protein	Crude protein is the measurement of total protein content in feed
Defatting	A step within the processing of feed materials which involves removing the lipid, or fat, content of the material to concentrate the protein content.
Edible insects	Species of insects used for human consumption (for example, mealworms, grasshoppers)
Feed conversion efficiency,	Represents the proportion of food converted into meat and is calculated by dividing daily feed intake by average daily weight gain
Farmed animal	Any animal that is kept, fattened or bred by humans and used for the production of food, wool, fur, feathers, hides and skins or any other product obtained from animals or for other farming purposes.

Feed or 'feeding stuff'	Any substance or product, including additives, whether processed, partially processed or unprocessed, intended to be used for oral feeding to animals.
Feed business/ industries	Any undertaking carrying out operation of production, manufacture, processing, storage, transport or distribution of feed including any producer processing or storing feed for feeding to animals on his own holding
Feedstock	The raw material(s) required to supply or fuel a machine or industrial process.
Feed supplements or additives	Tend to work at the microbe gut level and fall into two categories; replacing a medicine such as antibiotics or reducing the methane production in the gut
Fermentation –	proteins from fermentation-based systems (based on algae, bacteria, fungi or gas-/ energy-based systems), and cell culture technologies that are primarily developing lab meat products
Food	Refers to any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be, ingested by humans.
Flexitarians,	Person that eats mainly vegetarian foods but occasionally eats meat and fish as well
Food Waste	At each stage in the value chain, 'waste / food waste' is defined as: any meat product, or animal-derived material sent to a waste destination (including anaerobic digestion, incineration /controlled combustion, rendering with minimal valorisation (typically category 1 rendering), land application, sewer/wastewater treatment). For the purpose of this publication focused on material that, if managed differently, could have remained in the food chain.
Frass	The excrement of insects. Frass is high in nitrogen and a by-product of insect farming.
Hydrolysed proteins.	Proteins which have been broken into their smaller constituent parts, including large peptides, small peptides and/or amino acids, by hydrolysis. This enables the extraction of protein from animal by-products, brewers' grains and plant material containing anti-nutritional factors. Hydrolysed protein derived from these permitted materials may be added to feed to improve growth
Insect meal	A high-protein dry meal that is derived from the processing of whole insects.
Insect protein	Proteins for consumption as food or feed derived from rearing insects. Insect protein could refer to the meal, whole or hydrolysed forms.
Lab grown meat	Lab grown meat is also knows as 'cultured meat' or 'cultivated meat' and refers to meat that is grown using the stem cells of an animal, without the need for animal slaughter.
Metabolisable energy (ME)	Is the amount of energy within feed that is actually absorbed into the body (e.g. not the total energy available within feed).
Methane	Gas with no smell or colour that is often used as a fuel, but is a potent green house gas aand it is produced naturally from waste and ruminants.
Single celled protein (SCP)	Source of highly nutritious protein produced from controlled fermentation process and photosynthesis. It is used as a replacement for plant based proteins or fishmeal or animal protein
microbiota	Is a community of micro-organisms found in a controlled environment – often used when referring to the community of bacteria in the gut
Monogastric	Organisms that have single-chambered stomachs, such as humans, horses, pigs and chickens.

Nutrient	Any substance plants or animals require to live
Plant-based proteins	A meaningful source of protein derived from plants (for example, soy, hemp seed and ancient grains such as quinoa).
Pescetarians	Someone that eats fish but not meat
Novel systems –	new aquaculture, insect proteins
Docosahexaenoic acid (DHA)	A polyunsaturated omega-3 fatty acid. These can be produced by micro-and macroalgae, and can be synthesised from linoleic acid by animals. DHA is present in fishmeal and fish oil and is an essential component of fish nutrition.
Eicosapentaenoic acid (EPA	A polyunsaturated omega-3 fatty acid. These can be produced by micro-and macroalgae, and can be synthesised from linoleic acid by animals. EPA is present in fishmeal and fish oil and is an essential component of fish nutrition.
Processed animal protein (PAP)	Protein derived from animals that have been through a stage of processing. This includes meat meal, bone meal, blood meal, dried plasma and other blood products, hydrolysed protein, hoof meal, horn meal, poultry offal meal, feather meal, dry greaves, fishmeal, dicalcium phosphate, gelatin and any other similar products, including mixtures, feeding stuffs, feed additives and premixtures, containing these products.
Ruminant	Herbivorous, hoofed mammals which digest food via fermentation across four stomach chambers, enabling more efficient uptake of nutrients from feedstocks. These include livestock such as cows, sheep and goats.
Straight feeds	Feed sources mixed on farms
Substrate	The surface or material on or from which an organism lives, grows or obtains its nourishment.
Surplus	The quantity of material left over once requirements have been met, or an excess of production or supply.
Transmissible spongiform encephalopathies (TSEs)	A group of fatal and rare degenerative brain and nervous system disorders. TSEs are known to be transmissible from livestock to humans via the consumption of contaminated meat and result from ruminants consuming ruminant material.
Waste	Substance or object which the holder discards, intends to, or is required to discard and further defined in Article 3 of Directive 2008/98/EC

"Given the urgency of the climate and biodiversity crisis, we need to move to sustainable supply chains fast. We simply don't have the luxury of time. We have to scale up sustainable innovations much faster than we have in the past. We need approaches that work for innovators, large corporates and investors alike - and that bring measurable benefits for people and planet." Thomas Vellacott, CEO, WWF CH

Proteins & Feed

This chapter explores some global key themes and trends around alternative proteins that specifically impact the sustainability of the livestock sector from the perspective of feed and examines where there might be opportunities that Ireland has the potential to take advantage of. The report firstly explains some very broad trends in alternative proteins it then goes on to discuss nutrient sources in animal feed, and alternative proteins and their feed production techniques; we emphasise the potential for aquafeed. We then explore human diets and alternative proteins before opening up the analysis to understand key influences on innovation in this space before explaining the specific potential of the Feed-X process. The environmental impact of feed is briefly discussed as it provides context for the entire enterprise of feed innovation. The Chapter finally offers some Ireland specific views on innovation potential and proposes a set of recommendations.

3.1 General Trends in Feed and Alternative Proteins/Oils

- **Significant Growth in soy – increased supply risk:** according to WWF/GTZ report[33] almost 80% of the world's soybean crop is fed to livestock, especially for beef, chicken, egg and dairy production (milk, cheeses, butter, yogurt, etc). Soy oil is used for cooking and within a variety of consumer goods. Soy production has more than doubled over the last two decades. This has come at an environmental cost through forest conversion in many tropical countries. The EU is in the process of finalising a regulation on deforestation free products, which includes soy. A lead soy producer is Brazil, and according to WWF, over half of the Cerrado's 100 million hectares of native landscape has been lost to livestock and soybean farming. Three quarters of imported soy products (70-75 percent) being used as a cheap source of protein feed[34]
- **Localisation in feed production:** Some of the biggest economic disruptions from the COVID-19 pandemic were experienced in food supply chains, particularly in the protein sector, such as meat, dairy and fish. Pandemic-related disruptions to these supply chains have generated interest in improving supply chain robustness and resilience. This includes encouraging local and regional processing operations and creating shorter supply chains. Another consequence has been that consumers are increasingly interested in local and regional food options[35]

33 Cabezas S.C., et al 2019. Towards more sustainability in the soy supply chain, GTZ

34 Cabezas S.C. et al 2019 Towards more sustainability in the soy supply chain: How can EU actors support zero-deforestation and SDG efforts? 2019, GTZ

35 Anderson JD, Mitchell JL,Maples JG. Invited Review: Lessons from the COVID-19 pandemic for food supply chains. Applied Animal Science. 2021 Dec;37(6):738–47. doi: 10.15232/aas.2021-02223. Epub 2021 Nov 23. PMCID: PMC8617279.

- **High energy costs – fertilizer & feed increasing:** According to a recent House of Lords report[36] 2022 data shows that concentrate animal feed prices have increased by 15.6% over the past 12 months. This increase has been largely due to the price of sunflower meal (a by-product of sunflower oil), soyabean and wheat, which have been affected by the war in Ukraine, higher demand as economies increase production post pandemic and the high cost of fertilizers. Record-breaking gas prices have driven the cost of fertilisers up by 151% on an annual basis. In Ireland September 2022 prices are reaching 1000 Euros/ton, putting producers and farmers under enormous financial strain.
- **Feed with methane busting additives – climate smart cows:** Analysis from the Institute for Agriculture and Trade Policy and Changing Markets Foundation[37] was found to state that emissions by five meat and 10 dairy corporations, equated to more than 80% of the European Union's entire methane footprint and accounted for 11.1% of the world's livestock-related methane emissions. Methane, expelled by cows and their manure, traps heat 80 times more effectively, according to the UN. Neither countries nor companies are expected to meet their net zero or emissions targets without supporting innovation that addresses methane produced by livestock. Currently there are seen to be four main options: Produce less meat, eat less meat, feed innovations that reduce methane, and gene editing cattle methane production capacity. There is growing interest in having more grass-fed livestock systems that produce less methane, but the emission reductions gained are less significant, especially when scope 2 and 3 emissions are included.
- **Diets moving to more sustainable eating and food systems:** FAO notes that several governments are incorporating sustainability considerations into their food policies and consumer education programmes. This includes for example: having a mostly plant-based diet, focus on seasonal and local foods, reduction of food waste, consumption of fish from sustainable stocks only and reduction of red and processed meat, highly processed foods and sugar-sweetened beverages.
- **Plant based diet increasing:** In 2020, plant-based food sales were found to more than doubled (+243 percent)[38], with consumers putting 14 percent more meat-free and dairy-free options in their baskets. Researchers suggest that there will be 12 million consumers eating meat-free and a 98 percent rise in vegans[39]There are several drivers at play that have been consolidated during the pandemic; animal welfare/ethical concerns of eating meat, sustainability and carbon emissions associated with meat production and more recently convenience and money saving. Research has shown that, typically, cutting meat from your diet can save a lot of money – over €760 a year.[40]
- **Low Carbon – Net Zero Carbon Commitments:** The Paris agreement enshrined legally binding commitments to limit global warming to 1.5°C degrees in 2015, which came into force in November 2016. Several cotmpanies have gone on to sign up to the United Nations Global Compact's Business Ambition for 1.5°C initiative. Ireland is now on a legally binding path to net zero no later

36 Eardley, F. 2022, In Focus: Rising cost of agricultural fertiliser and feed: Causes, impacts and government policy. Published Wednesday, 22 June, 2022 House of Lords Library. Accessed 18/11/2022

37 https://www.theguardian.com/environment/2022/nov/15/methane-emissions-meat-dairy-companies

38 The Guardian 'What we eat matters' https://www.theguardian.com/commentisfree/2019/oct/08/climate-change-food-global-heating-livestock

39 NPD 2020 in https://www.newfoodmagazine.com/article/139141/plant-based-boom/ accessed 18/11/2022

40 https://www.bbc.co.uk/news/uk-42973870, https://www.irishexaminer.com/food/arid-40950818.html Irish Examiner 2022, N. Glennon, 31/08/22 online article: Cost of living: I cut meat from my diet for one week and this is what I saved. Accessed 6/12/22

than 2050, and to a 51% reduction in emissions by the end of this decade. The Climate Action and Low Carbon Development (Amendment) Act 2021 provides the framework for Ireland to meet its commitments. The role of food and feed in developing pathways to deliver these commitments is critical, especially in the livestock production.

- **Cheap meat availability:** The case that meat is now too cheap is getting ever stronger. Food prices do not reflect all costs relating to the production of consumption, like environmental costs, health and other costs. In addition, farmers often receive too low payments for a fair income. The low price margins make it difficult for either innovation or more sustainable farming practices, that are not as subsidised and are more expensive in the short term, to compete. The price squeeze for the end consumer is being felt even more with the cost of living crisis, but this has yet to filter through as the tight global supply of dairy and cattle ensures that Irish farmers are currently getting good prices.[41]
- **Price sensitivity in Ireland:** The 2022 Eurobarometer on food safety, asked about factors affecting food purchases, Irish consumers ranked cost (63%) as the most important consideration, with taste (54%) and then both food safety and nutritional content (both at 52%). Strikingly, these results are higher overall than the average top concerns across the whole EU. For both cost and nutrient content these scored 10% less across the EU than in Ireland. "75% of Irish people interviewed said they had a personal interest in the topic of food safety."[42] This compared with 70% for the rest of Europe. The most important food safety aspect for the Irish consumer was the risk of food poisoning (39% compared with 32% for the rest of Europe).
- **Alternative Protein Regulation:** The EC has legislated to enable alternative proteins as human food ingredients and as a feed ingredient for fish and poultry. This offers scale up opportunities

41 https://www.farmersjournal.ie/farmgate-price-rises-but-costs-increasing-623430 accessed 6/12/22

42 https://www.fsai.ie/news_centre/press_releases/2022_eurobarometer_03102022.html accessed 18/2022

3.2 Context: Nutrient sources in animal feed

Globally, livestock consume a variety of raw materials – including grasses (pasture), crop residues, cereal crops, as well as food and biofuel industry by-products and fishmeal (Figure 3.1 [43]). Pasture and fodder crops accounts for more than 54% of feed use in terrestrial livestock systems. The feed mix varies significantly by species, production system and region – for example from grain and soy dependent industrialized pig and poultry production in China to the by-product and crop residue based dairy systems of India and Pakistan.

Globally, pigs and poultry are the main users of concentrate feed – accounting for more than 60% of consumption. This is mainly in Eastern Asia, Europe and North America. Other research calculates grain use is even higher at 78%.[44] The materials used in these compound feeds are mainly cereals and oilseed meals – with a variety of other materials are also added in smaller volumes, e.g. minerals, dairy products, oils. Other notable feed ingredients include amino acids and distiller's grains. By-products from the bioethanol industry have become important sources of feed in recent years – providing a significant quantity of 'distillers grains' (Distiller's Dried Grains with Solubles (DDGS)). DDGS also uses maize and wheat as a raw material (Figure 3.2[45])

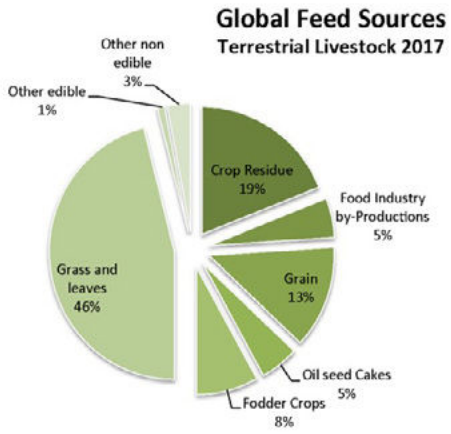


Figure 3.1: *Global feed sources for terrestrial livestock*

EU-27, Feed Material Consumption for Compound Feed Ind. 2020

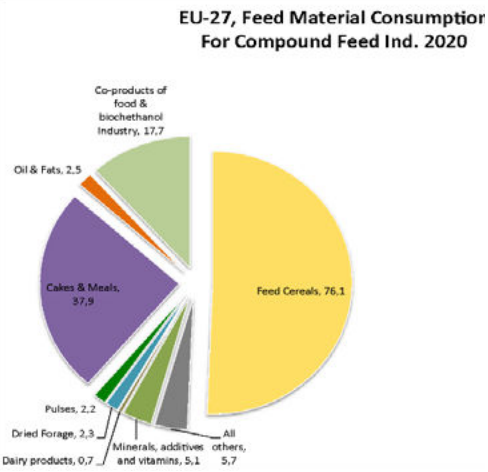


Figure 3.2: *Feed Material Consumption 2020: Feed material consumption by EU27+UK feed industry, 2020 and totalling 150.2 million Metric*

43 Mottet, A., et al. (2017) 'Livestock: On our plates or eating at our table? A new analysis of the feed/food debate', Global Food Security, 14, pp.1-8. DOI: https://doi.org/10.1016/j. gfs.2017.01.001.

44 Herrero M, Havlík P, Valin H, Notenbaert A, Rufino M C, Thornton P K, Blümmel M, Weiss F, Grace D and Obersteiner M 2013 Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems Proc. Natl Acad. Sci. USA 110 20888–93

45 FEFAC, 2020. Feed & Food Statistical Yearbook 2020

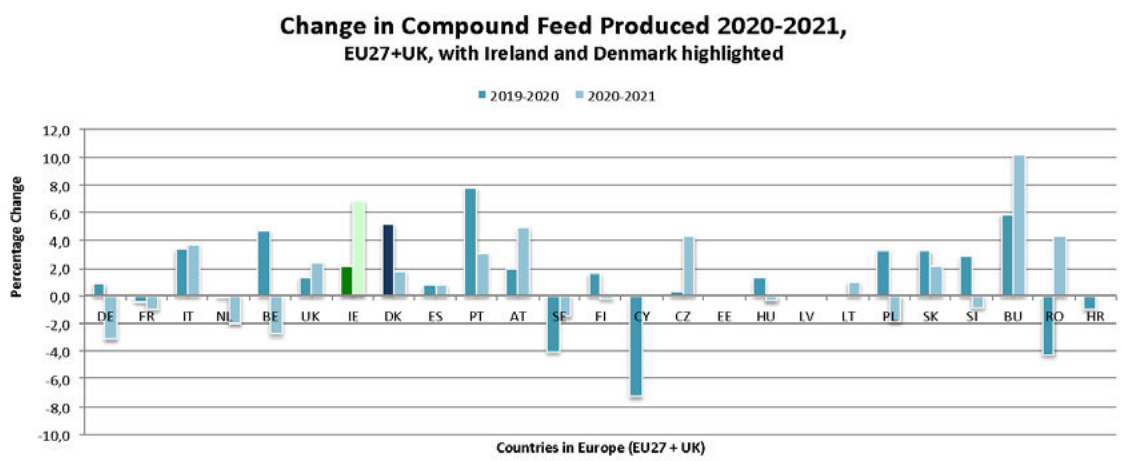


Figure 3.3: *Percentage Changes in the Compound Feed Production in 2019-2020 and 2020-2021*

There are various sources estimating total global feed use (see Table 3.1). These are either academic studies that model the theoretical feed requirements of livestock populations, or feed industry publications that are based on surveys and corporate reports. The latter focuses on 'compound' feed products and overlook feed crops grown by farmers and 'straight' feeds that are mixed on-farm. We estimate that the total amount of all types of feed (including grazing) consumed by livestock today is 6 billion tonnes. If compound feed growth is in line with FAO projections[46], then its estimate an additional 250m tonnes of feed per year will be needed.[47]

Table 3.1: *Global livestock feed tonnage data – key sources*

Livestock type	Scope	Feed type	Source	Feed quantity (million tonnes)	Data year
All	Global production	Compound feeds	FEED-X estimate[48]	1,250	2030
All	Global production	Compound feeds	Industry data[49]	1,208	2021
All	Global production	Compound feeds	Industry data[50]	1172.7	2020
All	EU-27+UK production	Compound feeds	Industry data[51]	167.3	2021
All	Ireland	Compound feeds	Industry data	5.07	2021
All	Denmark	Compound feeds	Industry data	4.61	2021

46 Figure 3.8 in Alexandratos, N. and J. Bruinsma. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.

47 FEED-X 2018

48 Based on Figure 3.8 in Alexandratos, N. and J. Bruinsma. 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO. This chart shows oilseed meal and cereal projections between 2015 and 2030. We have estimated to be this at a compound annual growth rate (CAGR) of c. 1.2%. We have used this growth rate to extrapolate from current compound feed production (1,070m tonnes)

49 Alltech Global feed survey 2018. This report did not split out totals by species (e.g. aqua) in 2018, but did in 2016.

50 FEFAC (2020) Feed and food statistical yearbook - 2020

51 FEFAC (2020) Compound Feed Production (2020)

Ireland was one of the few EU countries to buck the trend and showed a significant percentage increase, over 6%, in production between 2020 and 2021 (Table 3.1). Denmark, a similar sized EU country and relatively comparable, had its significant increase in 2019 and 2020 and showed a much smaller increase which reflected contraction in feed production in the EU during 2020 and 2021[52].

Compound vs. straight feeds

Animal feed can either be grown on-farm or purchased from feed suppliers in the form of 'compound feeds' or 'straights' (single crops). Figure 3.4 shows, from a European perspective, the relative importance of home-grown cereals and forages to overall feed sourcing. The International Feed Industry Federation estimate that, at a global level, industrial compound has a slightly higher share of non-forage feed inputs: their latest reports state that on top of the 1 billion tonnes of feed produced by the feed industry, around 300 million tonnes of feed is produced directly by on farm mixing.

This global commercial feed manufacturing sector has an annual turnover of over US $400 billion[53] and is undertaken by more than 28,000 mills[54].

From a global perspective, two thirds (66%) of compound feed produced is for the more 'industrialised' livestock sectors: pigs and poultry[55] (see Figure 5). It is estimated that 4% of compound feed is used in aquaculture[7] (c 40 million tonnes).

However, when feed production in Ireland is considered, it is a very different picture, with cattle and dairy dominating with 56%. More intensive production systems, such as swine and poultry, account for only 28% of Irish feed production. There is also no significant production of aquaculture feed. This reflects the regional and diffuse nature of the Irish feed market (with 140 mills) combined with the dominance of a few global aquaculture feed companies. However, there is also an opportunity here when the aquaculture production sector in Ireland is reviewed.

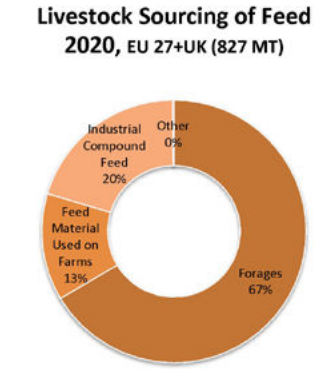


Figure 3. 4: *Livestock sourcing of feed : EU-27+UK*

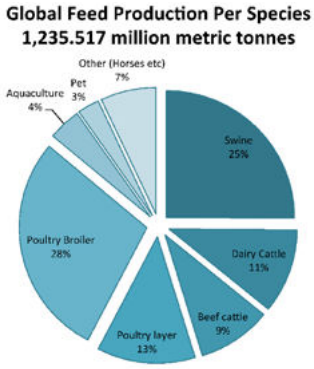


Figure 3. 4: *Livestock sourcing of feed : EU-27+UK*

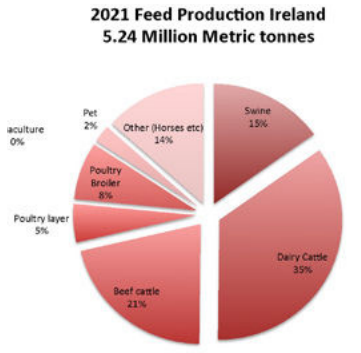


Figure 3. 4: *Livestock sourcing of feed : EU-27+UK*

52 FEFAC 2021
53 International Feed Industry Federation http://www.ifif.org/pages/t/The+global+feed+industry
54 Alltech Global Feed Survey, 2022
55 Alltech Global Feed Survey, 2021

In summary:

- The most growth in global demand for feed will come in next 12 years (from pigs, poultry & aqua culture)
- Deforestation expected to be driven by crops such as soy, maize in next 10 years – not grazing
- Easier to influence the compound feed sector as it is a relatively consolidated sector
- The largest price margins are in aquaculture and pet food, therefore any advances they make can be brought back into compound feeds for other species with lower margins
- Although Ireland may not have a local compound aqua-feed market it can take advantage of innovation in this sector and either apply it within its pet food production and or in its dairy and cattle industry.

Context: Aquaculture

According to the Global Salmon Initiative Cattle and dairy production have the highest carbon footprint of all the species. Unlike most of the species though it is highest due to the methane production during digestion rather than from the feed they eat. Farmed salmon on the other hand has a much lower carbon footprint than pork and cattle production (figure 3.7). It has also the lowest feed conversion ratio of all the traditional meat producing animals, meaning that it is the most productive animal to farm.

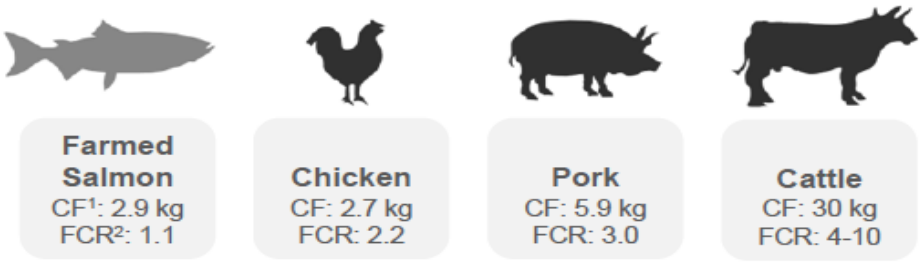


Figure 3.7: *Average Carbon Footprint (CF) in kg eCO_2 per livestock type*

There are various species in aquaculture with varying degrees of industrialisation and risks. There is what is known as the fishmeal trap. **The fishmeal trap:** "is the hypothesis that aquaculture is environmentally degrading because increased demand for feed leads to increased fishing for wild species used to produce feed, thereby threatening the viability of wild fish stocks, and that growth in aquaculture production will be limited by availability of wild fish used as feed in aquaculture production."

Carnivorous species, like salmon and sea bass, are most exposed to the fishmeal trap as they use the highest share of marine inputs in feed. Some omni- or herbivorous species, like tilapia, pangasius and shrimp, are also exposed as fishmeal is used to increase growth rate. High-value species, salmon and

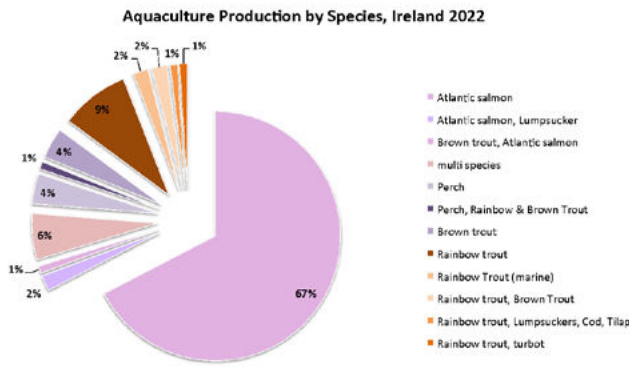
shrimp, play a more significant role in international trade. Although salmon and shrimp are relatively small in volume compared to other species, they are very visible products in many markets due to a high level of industrialisation and high R&D and innovation activities.

Today, the feed for the aquaculture industry is dominated by four main players: Skretting, Cargill Aqua Nutrition, Biomar and Marine Harvest (MOWI). They mainly produce feed for salmon/trout, shrimp and tilapia. Most of the feed used in salmon farming are produced close to where it is farmed, and therefore Norway and Chile are the countries producing the majority of salmon feed produced globally. Ingredients in fish feed are selected on the basis of available energy content and nutrient composition, and are mainly classified as sources of protein, energy, essential fatty acids, vitamins and minerals. Protein sources come from agricultural ingredients, mainly soy, and marine ingredients, represent fishmeal and fish oil. There are many suppliers and they sell to a range of different industries. Globally, Ireland is not seen as a main producer of Salmonoids but may have potential as Scotland's access to Europe changes going forward.

Aquaculture In Ireland

Aquaculture is in its early stages in Ireland with 101 fish farms along its west coast. Galway, Donegal and Cork are the areas of highest production. Ireland's marine farms occupy 0.0004% of Ireland's inshore area. Fin fish and shellfish are farmed in 15 Irish coastal counties. According to the Finfish register 2022, Atlantic Salmon is the main species produced by 70% of the units and Mowi Ireland owns 25% of all the aquaculture farms (figure 3.8).

In Ireland, most of the salmon is farmed, along with mussels and oysters. The industry sustains 1,833 direct jobs in remote rural areas – 80% in the west of Ireland. Every full-time job in aquaculture creates 2.27 other jobs locally (Teagasc 2015). According to Mowi Ireland 83% of people in coastal areas support the development of fish farming. Salmon is now the most popular fish bought by Irish families.[56]



56 MOWI Ireland website

Aquafeed Competitor activity

Businesses in the aquafeed sector are talking about and tackling environmental issues and opportunities. The aquafeed sector is expected to influence and shift the livestock feed industry due to its higher margins and larger R&D budgets[57]. The petfood sector, although smaller in size, also has potential to be part of this shift.

Aquafeed Corporate commitments

Raw material sustainability commitments and targets in the aquafeed sector are similar to those found in the wider food industry: deforestation is 'avoided' through the use of certification schemes.[58] None of the businesses have quantified commitments or targets to replace feed with novel raw materials. Different certifications are a commonly used way of verifying the sustainability and improve transparency and trust. The CEO of Cargill Aqua Nutrition, Einar Wathne, recently stated:" yesterday, one had to be transparent concerning the use of marine resources. Today this is expected by the market, and tomorrow it will be about taking leadership beyond our own commercial progress."

Context: Alternative Proteins and Feed Production Technology Trends

In general, dietary crude protein (CP) requirements for fish and crustaceans is high compared to livestock, crude protein is a key component of livestock feed and alternative proteins play a part. A major part of the dietary protein used in diets for livestock and aquatic animals in Europe is imported. Soybeans comprise the bulk of the protein import amounting to about 30 million tons annually, which is around 20% of the world production. Another key source of digestible protein is from fishmeal and fish oil, which is in short supply globally. These factors combine to explain in part why the aquaculture feed industry drives the search for alternative proteins.

- **Fish:** a range from 30 to 55% crude protein (CP) of dry matter and from 30 to 60% crude protein of dry matter for shrimp and other crustaceans[59]
- **Pigs:** range from 12 to 20% CP of dry matter for reproductive sows, from 20 to 25% CP of dry matter for piglets and from 13 to 20%. CP of dry matter for growing pigs[60]
- **Poultry:** the range is from 14 to 21% CP of dry matter for layers and from 20 to 26% CP of dry matter for broilers[61]
- **Cattle:** the range is from 10 to 19% CP of dry matter for growing animals and from 13 to 23% CP of dry matter for dairy cows [62].

57 Market Opportunity Report 2018, FEED-X

58 Market Opportunity Report 2018, FEED-X

59 Halver, J. D. & Hardy, R. W., (2002). Fish nutrition. 3rd edition. Academic Press, USA.; NRC, 2011 NRC, (2011). Nutrient requirements of fish and shrimp. Committee on the Nutrient Requirements of Fish and Shrimp, National Research Council of the National Academies. The National Academic Press, Washington DC, USA.

60 NRC, 2012, NRC, (2012). Nutrient requirements of swine. 11th revised edition. Committee on the Nutrient Requirements of Swine, National Research Council of the National Academies. The National Academic Press, Washington DC, USA.

61 NRC, 1994 NRC, (1994). Nutrient requirements of poultry. 9th revised edition. Subcommittee on Poultry Nutrition, National Research Council. The National Academic Press, Washington DC, USA.

62 NRC, 2001 NRC, (2001). Nutrient requirements of dairy cattle. 7th revised edition. Subcommittee on Dairy Cattle Nutrition, National Research Council. The National Academic Press, Washington DC, USA.

However, the level of Crude Protein required in the diet depends on the digestibility and the amino acid profile. It is not the crude protein levels as such that should be supplied with the diet, but rather the amino acids that are needed to build proteins in the body. For the mono-gastric and the aquatic animals, the diet has to provide the required essential amino acids in sufficient quantities and in the right proportions[63]. In contrast, the ruminants are less dependent on the amino acid profile of the diet, as they are provided with microbial protein (and amino acid) through the symbiosis with the rumen microbiota. It is the crude protein component of feed that alternative proteins aim to replace or partially replace. Given the large volumes used by the feed industry, supplying even just partially this replacement, gives a clear scale up journey for small companies.

Other components of feed that need to be considered are[64]:

- High ash content (e.g. insects, micro-algae) may interfere with the digestion and an unbalanced mineral composition with the mineral supply.
- Dietary fibre has an important role in diets for mono-gastric animals and a minimum level has to be included to maintain normal digestion, it may have nitrogen reduction benefits in manure for some livestock
- Grain legumes (such as faba beans, peas, lupines, soy beans) contain a number of anti-nutritional properties – eg. tanins
- High content of nucleic acids (DNA, RNA, nucleotides) in single-cell protein (SCP) and yeasts and fungi, may increase uric acid in the blood in some digestive systems
- There may be a risk for uptake and accumulation of heavy metals, pesticides, toxins and pathogens in insects, microorganisms and micro-algae
- Some SCPs may have the benefit of antibacterial properties

Given the nutritional performance of alternative proteins are tested for each species the following list of alternative proteins and feed production technologies have been curated and considered with their application to the Irish context.

Key Regulations Affecting Feed Novel Ingredients/Novel Foods

Although each country has its own peculiarities, in general the EU and the U.S. set the highest standards. Therefore, we consider it worthwhile to briefly analyse these two legal systems to assess the legal requirements for the introduction of alternative feed ingredients, which could then be introduced

63 Feed Protein Needs and Nutritive Value of Alternative Feed Ingredients by Lindberg J.E., Swedish University of Agricultural Sciences, Sweden in Nordic Alternative Protein Potentials Mapping of regional bioeconomy opportunities Jan Erik Lindberg, et al, Editors Kell Andersen and Knud Tybirk, Nordic Council of Ministers, 2016

64 Feed Protein Needs and Nutritive Value of Alternative Feed Ingredients by Lindberg J.E., Swedish University of Agricultural Sciences, Sweden in Nordic Alternative Protein Potentials Mapping of regional bioeconomy opportunities Jan Erik Lindberg, et al, Editors Kell Andersen and Knud Tybirk, Nordic Council of Ministers, 2016

at a global level too. Consequently, alternative ingredients, processes, technologies and innovative methods, which are not easy to introduce or experiment with in the EU or the USA, could be introduced or tested elsewhere.

EU Regulations[65]

This legal area is very detailed and complex. EU feed legislation alone is more than 70 000 pages. The main pieces of legislation are:

1. 2009 Regulation (EC) No 767/2009, which regulates the placing on the market and use of feed,
    a. The substantive general entry requirement for feed business operators using a feed material entered in the Catalogue is to ensure that it complies with Article 4 of the 2009 Regulation (EC) No 767/2009
    b. feed businesses have to ensure that the feed a) is sound, genuine, unadulterated, fit for its purpose and of merchantable quality, and b) is labelled, packaged and presented in accordance with this Regulation.
    c. Article 15 contains General Labelling Requirements (type of feed, name of business, batch number, list of feed additives, etc.), and
    d. Article 16 Specific Mandatory Labelling Requirements for feed materials.
    e. Specific requirements with regard to the quality of the feed that is placed on the market can be found in other legislative acts. Annex I to Regulation 767/200914 contains the rules on impurities and other chemical determinants,
2. Equally relevant, the 2017 revised EU Catalogue of Feed Materials (EU) Regulation 2017/1017 provides an extensive list, in its Annex C, of the ingredients that may be used for a feed material complying with the requirements of the entry concerned.
3. EU regulation 2021/1372 has authorized the use of processed animal proteins derived from insects (insect PAPs) in poultry and pig feed.
4. GMO feed irrespective of similarities to already approved GMOs the registration procedure for GMOs under Regulation (EC) 1829/2003 on GMO food and feed requires more extensive safety assessments.
5. Directive 2002/32/EC lists maximum levels for undesirable substances in animal feed, plus maximum residue levels of pesticides in food & feed of plant & animal origin.
6. If the ingredient constitutes a feed additive, it has to obtain authorisation under Regulation 1831/2003. The authorization criteria are that the additive has no harmful effects on human and animal health and on the environment.

If a manufacturer or importer wants to place a new ingredient on the market, they have to obtain approval in accordance with the procedures of these Regulations.

65 Extracts from Keessen A.and Kajic, M. 2019, FEED-X The Path to Legally Introducing a New Fishmeal Recipe Utrecht University 2019

U.S. Federal law[66]

In the U.S., the Federal Food and Drug Administration (FDA) is responsible for monitoring the safety of food and feed products. The 2007 Federal Food, Drug, and Cosmetic Act (FFDCA) govern the use of food products, and the Regulations issued under its authority. The U.S. legal system offers less ingredient-specific variation than the EU system. According to US legislation, it is possible to place on the market only products (food or feed) which fall into: a) additives; b) products generally recognized as safe. Under sections 201(s) and 409 of the FFDCA new food ingredients fall under the definition of food additives, i.e. any substance that is intentionally added to food. They are subject to premarket review and approval by the FDA. Once approved, they receive the status of Generally Recognized as Safe (GRAS).

- However, GRAS recognized status is not a mandatory pre-requisite for market entry.
- An ingredient can also be marked as entirely safe with "no questions" by the FDA.
- Once the safety conditions are met, the only further condition that needs to be met prior to market entry is labelling.
- Federal labelling conditions are outlined in CFR Section 501.110, on Animal feed labelling and collective names for feed ingredients.

Once the federal conditions for safety and both federal and state conditions for labelling have been met, the ingredient is entirely eligible for lawful market entry. While EU and US legislation are perceived to be very different, the outcomes are frequently the same. Although standards differ across countries, EU and US standards provide a high level of feed safety and consumer protection. Therefore, it is likely that an alternative, which can legally be introduced in both the EU and the US, can be introduced on a global scale.

Notable differences are:

- EU legislation takes a firm stance against cannibalism and this is unlikely to change.
- Similarly with sludge and manure – compliance is unattainable in the EU, but approved in the US,
- EU regulation 2021/1372 has authorized the use of processed animal proteins derived from insects (insect PAPs) in poultry and pig feed. In the US, insects are not approved in a federal level, so there is a lot of confusion in a state level.

Table 3.2 summarises the perceived regulatory barriers relating to insects and the substrates they feed off. Although originally focused on the UK, elements of interest to Ireland have been highlighted.

66 Extracts from Keessen A.and Kajic, M. 2019, FEED-X The Path to Legally Introducing a New Fishmeal Recipe Utrecht University 2019

Overall, the results show that regulation will frequently not constitute an obstacle to the introduction of alternative proteins and additives. One should not become overly optimistic though. Where approval is needed, it can be complex and time-consuming. In general, the more novel an ingredient is (e.g. a production that is not commonly used, using special strains of bacteria, yeast, algae and so on), the more complex and time-consuming the legal approval procedure becomes.

Place based advantages of Ireland for alternative proteins for feed/food

Ireland remains the key English speaking EU country that continues to have strong trade links to the UK and US markets. Geographically and demographically there are similarities with Denmark and New Zealand in terms of investment, so in part the points made here are reflecting on what those countries do well and could sign post future actions relevant to Ireland.

- **Marine** – kelp/mussels: As an alternative source of protein for the aqua feed industry mussels not only combine with the pens and feed of the excess fish feed, they can then be harvested for the feed industry as a source of fish oil and meal. Irelands abundant coast and existing aquaculture/ matriculate industries make this an area of specific interest for Ireland. Kelp Is being explored as another source of marine protein, techniques are still at early days but it may prove interesting in the future. Kelp could also be sustainability harvested as a substrate for insects.
- **Insects** – The most successful insect operations have been those that can locate themselves close to the source of the substrate and not pay to dry or transport the material. Innovafeed, an insect protein producing company, is co-located next to a starch manufacturing company to take advantage of the by-products for the insects feed.
- Precision fermentation technologies required for single based proteins is very similar to that employed by the breweries and distilleries.
- **Grass** –Ireland is already in an EU partnership to demonstrate the use of small scale bio-refineries converting grass into three co-products; firstly protein cakes that reduce methane in cows by 15%, Secondly Soy replacement for pig feed and with a third possible application for pet food and which may have a pro-biotic performance. The pro grÜn project. Ireland has 50% of land as grass so this is indicative of the kind of field trial investments needed.
- **Pet-food** – higher value and better price margins mean that it can pull through the innovations similar to how the aqua-feed companies are pulling through alternative proteins so they can get to scale for the rest of the feed industry faster.

Table 3.2 *of Perceived regulatory barriers of Insects and substrates*

Current laws preventing insects in animal feed
Insect protein is only authorised in aquaculture, poultry and pig feed Draft EU regulations allow insects to be used as animal feed, but there is uncertainty with UK regulations following Brexit. The current situation prevents European or global insect producers looking at the UK, as the regulation is prohibitive to growth. It also prevents investment in insect production as too many legal hurdles to overcome at present. This may offer an opportunity for Ireland
Lack of a strategic policy framework
There is currently no Irish or UK government strategic policy framework to support the insect industry.
Restriction on substrates that can be used
Current legislation around using mixed food surplus and post-consumer surplus restricts the opportunity for insect farmers to utilise this material.
Planning permission
As with many industries, there can be difficulty when trying to obtain planning permission. This can include objections from neighbours regarding pollution, noise and odour from insect farming.
Classification of insects as a farmed animal
Confusion over the current classification of insects. Insects being classed as an animal means that veterinary controls are required for the slaughter of insects. This classification also prevents substrates such as manures being fed to insects.
No classification of 'organic'
There are no guidelines to show what an organic insect farm would look like which makes it challenging to state whether insects are organically produced. This presents a barrier to where insect protein can be used as it would not be permitted in organic fish.
Regulation of insect frass
No clear regulation around how to treat insect frass which prevents this being sold or used by farmers as a fertiliser. This can be sold to the home market at present, for gardeners to use, but it is considered a 'grey' market.
Lack of a 'protein strategy' in the UK and Ireland
Niether Country has a 'protein strategy'. This compares to many other EU member states that have and which has enabled these states towards faster advancement in looking for and investing in alternative protein sources. Stakeholders estimate that the UK is 10 years and €1.5 billion behind European leaders in this space.
Lack of an industry standard
The food and feed industries have been encouraged to be self-regulating and that's fine to manage 'business as usual' however this environment isn't conducive to encourage emerging technologies and applications.
Permitted substrate materials
Current legislation only permits a small range of materials that can be used as substrates by insect farmers.
Geographic spread of substrate material
The geographic spread of permitted substrate materials creates challenges for achieving required volumes to meet demand.
Consistency and seasonality of substrates
It can be challenging to find a permitted substrate material that has a consistent supply that is available every week of the year to meet demand.
Competition with disposal
Anorobic digestion and incineration are heavily subsidised and already well established which can create competition for materials. Re-routing these materials may have unintentional impact on other sectors.
Contamination risk
Perceived concerns over the contamination levels in the substrate material.

Credit : Shutterstock

A recent report for the New Zealand government looked at the levels of current investment in alternative proteins across 10 different countries (including Ireland) and across 6 different protein technology types. Key points have been extracted here to highlight the areas of focus that might be interesting for Ireland[67].

- Of the approximately $900 million USD government investment by the ten countries included in the reports analysis, around 73% was for activities related to specific protein sources.
- The remainder was for initiatives supporting the general development of alternative proteins or where the details of funding allocation had not yet been announced.
- The $900 million USD does not include the €25B committed by The Netherlands government to reducing livestock numbers, nor investments of undisclosed amounts by governments into private companies.
- Where governments have announced a single investment into several initiatives where only some are related to alternative proteins, it was assumed the funds were equally shared between the initiatives and only the proportion related to alternative proteins was counted.

The report also considered whether the country was investing in the production of the protein source, the processing of the protein source into ingredients or foods, or the development of intellectual property with the intention that other countries would be likely to undertake the production and food manufacture. Only 5 of the countries have been chosen to highlight in the following table due to their relevance to Ireland, either geographically or market wise.

67 Government investment in the opportunities of alternative proteins; What are other countries doing and how does Aotearoa New Zealand compare? Emerging Proteins NZ, Food HQ and Agmardt 2022

Table 3.3 provides an overview of the level of focus each country has based on these aspects and includes Methane busting additives due to the similarity of the technologies involved and their relation to the feed industry.

Table 3.3: *Summary of the areas of investment in types of alternative protein technologies*[68]

Protein Types	Netherlands	Denmark	New Zealand	United Kingdom	Ireland	Pros for Ireland	Cons for Ireland
	PD:PS: IP	PD:PS: IP	PD:PS: IP	PD:PS: IP	PD:PS: IP		
Plant Based	Moderately Strong Focus-all	Moderately Strong Focus-all	Low focus - all	Strong focus – all	Moderately low focus - all	Experience on Grass & legumes	Crowded with Au and Ca leading
Cell Based & Precision Fermentation	Moderately Strong Focus-all	Moderately low focus - all	Low focus - IP	Moderately low focus - all		Build from experience fin distilleries	No investment so far
Insects	Moderately low focus - all	Low focus - all		Moderately low focus - all		Potential Link to potato water	Depends on substrate availability
Fungi				Low focus - all		Only 3 others investing here	Limited experience to build on
Algae/ seaweeds	Low focus - all	Low focus - all	Low focus – PD & IP	Moderately low focus - all	Low focus - all	Coast & existing aqua-culture experience	Crowded & expensive
Methane busting additives	unknown	unknown	unknown	unknown	unknown	Offer field trials – opportunity for investment	Few tech-nologies, Au, Sweden, US leads

Key:
PD – ***Production*** *is defined as "any activities that are captured in the growing and development of raw materials to be further processed".*
PS – ***Processing*** *is defined as "any series of mechanical or chemical operations on a primary product to change its form".*
IP – ***Intellectual property*** *is defined as "any work that is undertaken to develop copyrights, patents, trademarks and trade secrets relevant to alternative proteins".*

In terms of the other 5 countries assessed in the original analysis, Australia and Canada both had a strong focus on plant based proteins in all aspects. Of its scale up journey. Netherlands, Denmark, and UK all had moderately strong focus; Sweden had a moderate focus and Singapore, Israel and Ireland were deemed to have moderately low focus, with New Zealand having just a low focus. This demonstrates that plant based proteins is receiving a lot of investment focus globally, Ireland can compete here but they could take advantage of plants commonly occurring in Ireland like grass and clover.

68 Adapted from table 2 in Government investment in the opportunities of alternative proteins; What are other countries doing and how does Aotearoa New Zealand compare? Emerging Proteins NZ, Food HQ and Agmardt 2022

3.3 Context: Human Diets and Alternative Proteins

What we eat and the link to our health is well established, FAO found that 83 countries have National Dietary Guidelines (NDGs)[69]. The NDGs seeks to balance the food groups to ensure local populations can eat more healthy choices. The link to how our diet impacts the health of the planet, is much less established, the same FAO review identified 15 countries whose governments incorporated elements of sustainability into their guidance. They also analysed the Livewell diet[70], a WWF UK initiative and the Barilla double pyramid. More recently Eat foundation for the Lancet commission[71] and WWF[72] have even considered human diets in 147 countries that use resources within boundaries that the planet can provide. Which is a more rigorous analysis of the sustainable diets. These approaches recognise that National Dietary Guidelines (NDGs) are important tools for changing diets and act as a bridge between global dietary recommendations and local context and relevance. However, they also note that current NDGs, are not ambitious enough to achieve global goals and commitments and should therefore be reviewed and updated to ensure they are in line with global health and environmental targets[73]. The common recommendation is a shift in the proportions of food groups on the plate to lower animal proteins and dairy, which have the higher emissions and increase vegetables as well as plant-based proteins. The EAT-Lancet example is given in figure 3.9.

Figure 3.9: *Sustainable and Healthy Diet (EAT-Lancet)*

The WWF (2020) report went further and compared a regions current diet with their NDG recommended, then the proportions for flexitarians, pescatarians, vegetarians and vegans. Thus, acknowledging that it's those countries with the higher nutritional intake (as much as 2000 g/day for the USA compared to 1000 g/day for Indonesia) that need to shift their diets first. Taking Europe as a region the proportions for each diet type is presented in figure 3.10. Current per capita food consumption patterns in European countries and the food intake (g/day) required to shift toward NDGs and other dietary patterns.

69 Gonzales Fischer, C. and Garnett, T. 2016. Plates, pyramids and planets: Developments in national healthy and sustainable dietary guidelines: a state of play assessment. FAO and Food Climate Research Network

70 WWF (2017) Eating for 2 degrees; new and updated Livewell Plates Summary report. Revised edition Kramer et al. WWF UK, Woking UK.

71 Summary of the Commission Food in The Anthropocene: the EAT-Lancet Commission on Healthy Diets From Sustainable Food Systems. The entire Commission can be found online at thelancet.com/commissions/EAT

72 WWF (2020). Bending the Curve: The Restorative Power of Planet-Based Diets. Loken, B. et al. WWF, Gland, Switzerland

73 WWF (2020). Bending the Curve: The Restorative Power of Planet-Based Diets. Loken, B. et al. WWF, Gland, Switzerland

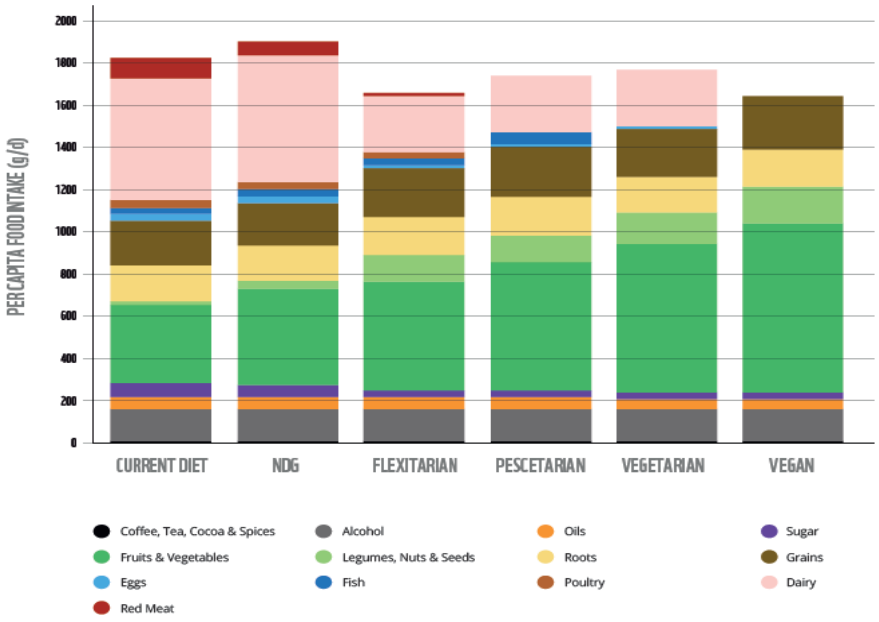


Figure 3.10: *Comparing Diet Types (WWF)*

Ireland does have an NDG with its own national diet recommendation and represented as a pyramid (Figure 3.11). It differentiates itself by keeping animal and plant-based proteins in one group. The Irish NDGs do not talk of the sustainability of this diet, its focus is on purely health benefits. The Irish government have also done some consumer awareness research on whether these dietary shifts are indeed taking hold.

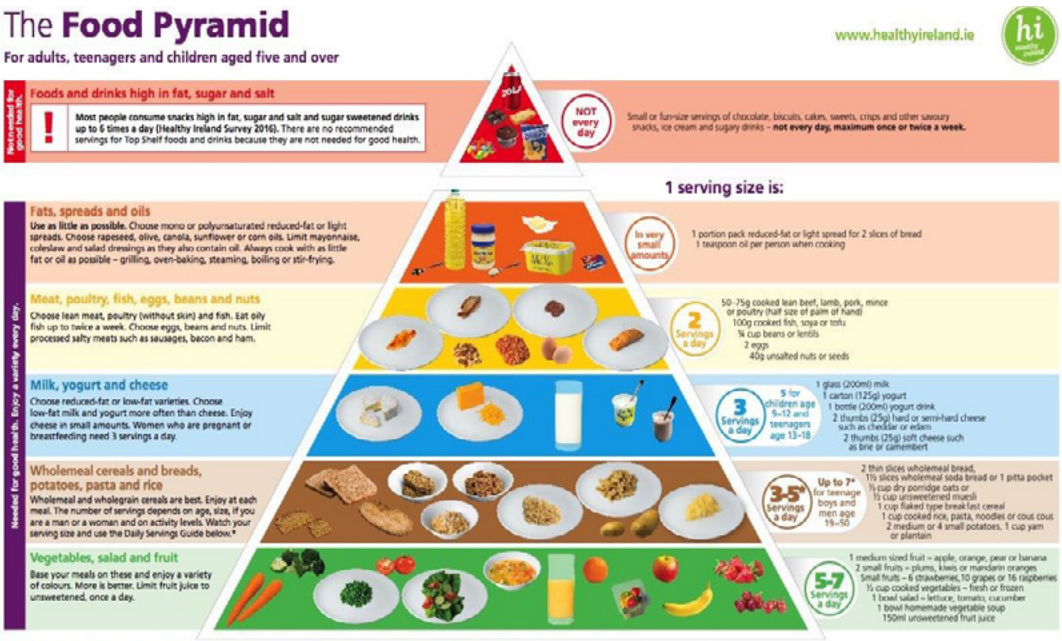


Figure 3.11: *Irish national diet recommendation represented as a pyramid*

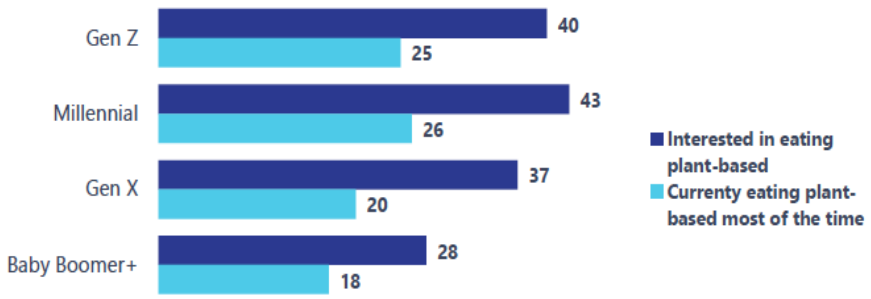


Figure 3.12: *Eat Forum report comparison - What consumers say and what they eat*

In a 2022 report Eat foundation[74] has explored how likely this shift is from a consumer perspective, and Bord Bia has specifically considered the Irish consumer (Figure 3.12). It was found that while eating healthy food has remained steady, there was a small but steady increase in eating vegetarian/vegan food over the past three years (2019 to 2022). It was also found that the younger generations were more interested in eating plant-based protein, however noting there was a difference between what they were actually eating.

Global meat consumption is still growing at a steady pace due to markets in Asia Pacific, Middle East, Asia and Latin America (Figs, 3.13 and 3.14). These markets are expected to drive growth in meat and account for 85% of the absolute volume gains.[75] The same Bord Bia report[76] states Meat production is expected to grow by 60-70% over the next 30 years according to FAO 2011.

The projected value of the protein ingredient market is $58.49 billion in 2022 according to Market and Markets 2017.

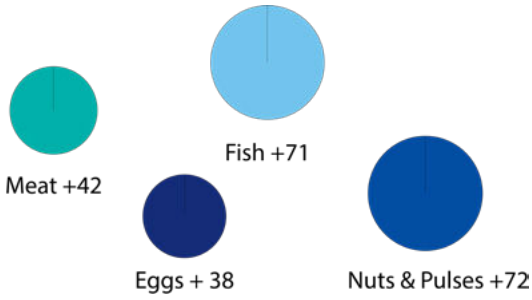


Figure 3.13: *Volume of protein type sold globally.*

74 Grains of Truth 2: EAT - GlobeScan global consumer research on a sustainable food system
75 Euromonitor International 2017 in Bord Bia Protein Playbook 2018
76 Bord Bia Protein Playbook 2018, How to innovate and differentiate in the world of protein

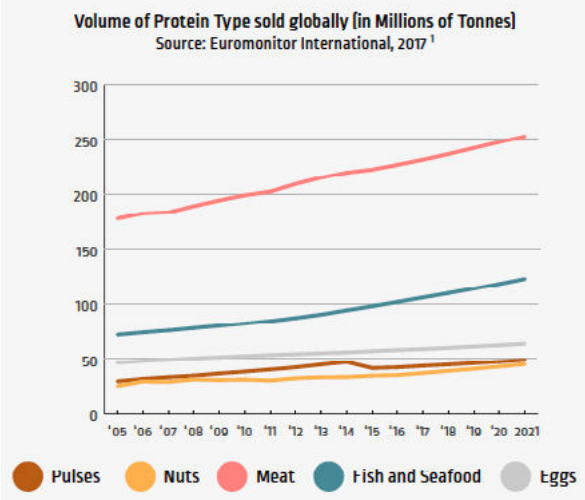


Figure 3.13: *Volume of protein type sold globally*

There are several key protein sources to note:

- **Casein** – Extracted from mammalian milk
- **Ancient grains** – Higher protein sources such as quinoa, amarah, and millet.
- **Algae** – modified it can rival soy as a protein source
- **Hemp and Lupin** – both high in protein, omega 3 and fatty acids.

Although not a plant-based protein the report recognises that Insects have been eaten as a source of protein for many years in Asia, Africa and Latin America and are estimated to supplement the diets of 2 billion people (UN Global News 2013). There is a "yuk" factor to contend with. The Bord Bia conducted their own study comparing consumer attitudes in Ireland with 8 other countries in 2021[77], taking account of changes after the pandemic.

- 50% of Irish respondents stated that they like to cook from scratch,
- 16% of the Irish adhere to a flexitarian diet,
- 18% are buying less but better quality meat,
- Several consumers questioned how healthy it was to follow a vegan diet,
- 30% think that meat free alternatives are highly processed.

In the next 10 years most people stated they would be eating

- chemical free food (49% will do this, 28% will not and the remaining hard to say).
- Plant based food instead of meat (42% will and 31% will not).

77 Bord Bia 2021, Dietary Lifestyles, Thinking house, & empathy power point.

Drivers of Innovation

For the purposes of this analysis, we have focused on the three market-focused trends that we believe create the strongest case for innovation in the feed industry, but also for the broader livestock production system:

- **Consumer preferences** – environmental, health & animal welfare concerns
- **Retail and environmental commitments** – transparency, climate change and deforestation
- **Environmental, Social & Governance (ESG)** risks affecting investment and agri-foods supply chains.

Although aquaculture feed production in Ireland is so small it is negligible, there is still potential to develop it or the alternative proteins that could replace or partially replace crude protein (CP) from soy or fishmeal.

Consumer preferences

The increasing popularity of 'plant-based' products, 'alternative proteins' and flexitarianism has become a key consumer trend in some markets over the past five years. For example, more than a quarter of meat-eating British people have reduced or limited their meat consumption in the last six months as a result of environmental, animal welfare and health concerns[78,79]. Global product launches with a plant-based claim saw a 63% compound annual growth rate between 2011 and 2015[80]. These products have now moved firmly into the mainstream – if still only a small part of the overall market. Consumers say they are being influenced by high profile NGO and public health campaigns such as 'Meat Free Mondays' and Veganuary[15]. Low-meat foods and diets have gone from being relatively untrendy to being aspirational – especially amongst younger consumers who are avoiding meat on animal welfare *and increasingly on* environmental grounds[15].

In response to this trend, traditional meat businesses and venture capitalists are investing in start-ups targeting alternative proteins. These offer the potential for disrupting whole categories – such as meat and dairy. A good example is news that Tyson Foods has taken a stake in cultured meats company Memphis Meats. The company has a $150m fund targeting long term investments that will keep the business relevant in the future[81]. Similar innovations are being explored in fish – for example California-based start-up Finless Foods aimed to achieve price parity with Bluefin tuna by the end of 2019.[82] Dairy alternatives are also increasingly popular with consumers – a trend that prompted Danone to

78 Mintel's Meat-Free Foods UK Market Report

79 Protein Industries Canada (2017) Protein Macro Market Drivers

80 Fitzpatrick, K. 2017 Plant-Based Proteins. Presentation March 2017 for Ag-West Bio. Saskatoon

81 Forbes Magazine (Jan, 2018) Tyson Invests In Lab-Grown Protein Startup Memphis Meats, Joining Bill Gates And Richard Branson

82 Food Navigator USA (Dec, 2017) Cultured fish co Finless Foods aims to achieve price paritywith Bluefin tuna by the end of 2019

acquire US-based WhiteWave Foods, which operates under the Alpro brand in Europe. Indeed, in 2017 the 15 most well-funded food and drinks start-ups had a major focus on plant-based products (with a combined investment of $1.5bn[83]). It goes without saying that these sorts of protein product innovations that by-pass conventional livestock altogether could potentially pose a long-term threat to the feed industry.

Retail and Environmental Commitments

Retailers are also positioning themselves – for example Tesco now has an Executive Chef-Director of Plant Based Innovation and Marks & Spencer included a number of commitments to promote plant-based alternative proteins within the 2017 refresh of its Plan A programme.

According to a WWF report[84] Six of the UK's ten major supermarket retailers have published time-bound commitments to source and support the move to deforestation and conversion-free soy, along with action plans outlining how will get there. Several of the UK supermarkets now have feed policies as it relates to hidden soy and in order to promote alternative proteins were they can; for example Tesco, Co-op and IKEA.

ESG and feed alternative proteins in Ireland

The final area of increasing interest is the growth in interest from the investor community in environmental, social and governance (ESG) risks. Consumer, customer and investor concerns are aligning around a core set of key environmental and social issues that are of particular relevance to global meat and aquaculture industries. These are: animal welfare, public health, climate and water risk and deforestation. There is a risk that livestock systems are by-passed through the development of novel plant-based protein products – so livestock feed innovation will be essential to demonstrate that sustainable terrestrial livestock and aquaculture systems offer credible solutions to these global concerns.

Four of the most popular issues – i) climate change, ii) human rights/labour, iii) water risk and iv) animal welfare – are of particular relevance to the livestock sector.

The importance of **climate risk** (including deforestation risk) has been championed by heavy-weights within the investor community – particularly since the 2007 economic crises shone a light on the importance of understanding systemic risks. The Task Force on Climate Related Financial Disclosures has identified sectors such as agriculture and transportation as being particularly vulnerable to the physical risks associated with climate change[85]. While the current focus is on the long-term financial viability of fossil fuel energy extracting industries it is likely that attention will turn to those sectors that have supply chains that are dependent on sectors at risk from physical climate risks, such as food retail

83 CB Insights (2017) All You Can Eat: The 15 Most Well-Funded VC-Backed Food & Beverage Startups

84 The UK Soy Story: How retailers' commitments to tackling soy-driven deforestation compares. WWF-UK

85 Task Force on Climate Related Financial Disclosures (2017) Recommendations of the Task Force on Climate-related Financial Disclosures. Final report.

and brands. While the rapid expansion of soy has brought many economic benefits to countries and producers, it has also been associated with significant **human rights and labour violations** such as land and water conflicts, forced labour and child labour.[86,87,88,89] As we have seen with palm oil, addressing the *social* impacts of soy production is likely to become as significant a driver of action as addressing well known environmental issues. **Water risk** has arguably become the environmental risk of greatest interest to business – given the more tangible operational impacts of water supply issues. Much like climate risk, the guidance advises that investors will increasingly expect businesses to Identify and disclose agricultural supply chain water risk.

The final ESG issue of interest to investors is **animal welfare and antibiotic use.** Leading the investor engagement in this area is the Farm Animal Investment Risk and Return (FAIRR) initiative. Since 2016, the initiative has been engaging food and drink businesses, supported by 57 investors now managing some $2.4 trillion. FAIRR positions itself as 'putting factory farming on the ESG agenda'. Their 2018 briefing summarises the case for pursuing 'plant-based profits' to avoid investment risks and seize opportunities.

3.4 Summary & Recommendations

Summary of key findings from our Contextual analysis:

- There are very significant and fast-moving trends that will influence the shape of alternative protein growth and will influence Irish strategy: Soy feed risk; High energy & fertilizer costs; Increasing localisation in feed production; cow methane; Net Zero policies; food price sensitivity; plant-based diets; 'chemical-free food' (49%);
- Ireland has its specific and unusual protein demand profile: low Pork, high Chicken (high intensity feed), high cattle/dairy (low intensity feed – with 36% of Irish farmers already self-sufficient), tiny aquaculture feed market, and a negligible human feed production to date.
- 2021 saw $5 billion invested in Alternative Protein companies via 258 deals, $1.9 billion in plant based proteins, $1.7 billion in fermentation and $1.4 billion in cultivation. Alternative seafood deals raised $175 million through 24 deals in the same year. Money is available, but ESG risks are high and opportunities hard to source.
- No data was found on private investment in alternative proteins in Ireland.
- Ireland advantages are in cell-based protein (but many competitors ahead) & algae/seaweed (only UK ahead).
- Precision fermentation has global potential (not yet being realised but available to those who invest well)
- The Irish government policy for a sustainable, smart agri-food sector, together with its ability to coordinate across Departments, together with the shift to a Challenge-Focused Innovation System, offer a unique opportunity to mobilise finance and develop an entirely new sub-sector within Irish agri-food.

86 RobecoSAM (2016) Engaging to mitigate risks in the soy supply chain

87 WWF The Social Impacts of soy: http://wwf.panda.org/what_we_do/footprint/agriculture/soy/impacts/social/

88 KPMG (2013) A roadmap to responsible soy: Approaches to increase certification and reduce risk

89 Amnesty International (2016) The Great Palm Oil Scandal: Labour Abuses Behind Big Brand Names

"One of the first countries in the world to develop a national agri-food strategy using a food systems approach"

Credit: Shutterstock

We recommend that Ireland:

- **Implements a cross-Government Strategy on Alternative Proteins.** There is a window of opportunity for the design and implementation of a sustainable transition for alternative protein for feed and human diets. The more complex, cross-ministry, challenge-led opportunities can take advantage of Irish government competence (where other Nations can struggle).
- **Responds to the changing needs of modern consumers** Further research is needed on human diets and consumption of sustainable food (especially those meat/fish which are fed by sustainable feed).
- **Develops a protocol and eco-system to support the adoption at scale of sustainable protein alternatives.** Market ready innovations alternative proteins are available. The demand for sustainable alternatives and technological innovations is growing. Government should unlock the power of procurement and invest in sustainable alternatives innovation that gain a multiplier effect from private investment.
- **Enables equitable access for alternative proteins** Government should create a level playing field for sustainable alternatives. A transition plan to enable alternatives to compete with incumbent solutions is recommended.
- **Addresses the growing concern for the health of our lands & oceans & biodiversity through alternative protein strategies that lead to regeneration.** Independent research on the true value of regeneration is recommended. This key trend toward regenerative agriculture will happen in parallel to any rise in alternative protein and must be integrated.

Finance mobilisation needs:

- **A Government plan to attract large amounts of Net Zero mission aligned capital.** The Impact of Capital Employed in sustainable alternatives is much greater than investment in other sectors of the economy. A funding Strategy to accelerate demonstration, transition and scale of sustainable alternatives is required.
- **Build a compelling investment case in a "sustainable system" pathway, with identified and de-risked returns, that helps accelerate the deployment of third party capital in this proven path.** Addressing the unrealised monetisation of value to design a compelling investment proposition to private and public funders and attract capital and distribute value to all stakeholders
- **To advance the narrative, rethink the incentives and make a tradeable asset to support the sustainable alternatives space**. Since 2018, 69% of all Forestry and Land use issued credits were Avoidance/Reduction credits.

The Potential Ireland Holds

Given this context, Ireland offers some unique opportunities when it comes to developing an alternative protein market.

- **Grass:** This is both as a source of extracted protein powder similar to pea or soya and as a source of food for bacteria, yeasts and fungi. All of which are considered novel ingredients by the feed industry.
- **Legumes:** Pea and Faba beans are a research priority for MOWI in exploring novel ingredients. These are both crops possible to be grown in Ireland, although the tillage season is not as long as other countries.
- **Exotic crops:** Protein from fungi (filamentous fungi) is one of the more established markets for alternative meats, but there is growing interest in proteins spun from non active hemp or European grown soy protein concentrate.
- **Fish offcuts:** A recognised rich source of fish meal and fish oil, the fishing industry provides this.
- **Poultry off cuts:** Although a smaller sector, feathers and other off cuts are being explored as fish meal protein replacements by both Skretting and Biomar. Currently feather meal is also being explored as a soil improver, and has the capacity the repress specific soil pathogens.
- **By-products:** The brewery and dairy sectors are both of a significant size and therefore offer consistent by-products at scale. It should be noted that brewer's yeasts and whey are already used in the feed industry.
- **Technical tendency:** U-protein and Smart Protein are at least two initiatives where Ireland is increasing its research capacity in this area. However, there are also projects (Horizon 2020) where scale-up engineering processes and technologies for alternative proteins are being explored, Denmark (DTU) and Sweden (Lund).

- **Investment:** 2021 saw $5 billion invested in Alternative Protein companies via 258 deals, $1.9 billion in plant-based proteins, $1.7 billion in fermentation and $1.4 billion in cultivation. Alternative seafood deals raised $175 million through 24 deals in the same year.[90] No data was found of private investment in alternative proteins in Ireland.
- **Innovation:** In terms of R&D investment by government bodies most notable in 2021 was Denmark with 1.25 billion kroner commitment to plant-based foods, EIT food, UK, Sweden and Norway were all identified as investing significant grant funds in plant based protein R&D. Irish Government investment in Alternative proteins is $6 Million or 0.14% of its GDP compared with Denmark $290 Million or 6.3% of its GDP.[91]

Ireland has potential to offer an interesting contribution to alternative proteins and other feed additives. The next section seeks to explore this through specific protein types and technologies.

Recommendations to grow the alternative protein sector in Ireland include many alternative protein opportunities:

- feed additive innovation (especially where it delivers methane reduction);
- coastal protein (algae, seaweeds, mussels);
- using potato water as food for insects (and a search for similar wastes that could drive protein growth);
- seeking human healthy diet / sustainability pyramid potentials (such as targeting certain conditions)
- cell based brewery industry co-products as source for alternative proteins;
- Fungi, Insects, Algae, Seaweed as source,
- Grass as a potential alternative protein feedstock (novel, with no global leaders yet)
- by products in general (needs better data on waste volumes e.g. fish co-products;
- any low methane feed additives (key dairy/beef challenge with current research in early phase but growing rapidly (such as Red Seaweed in Australia and Sweden [Blue Oceans Barns, Brominata, Symbrosia & Volta Greentech, Rumin 8], Seaweed mix (Nutri-san), Enzyme inhibitor 3-NOP (Bovaer), Yeast (Alltech), Essential oils (Agolin), Essential oil mix garlic & citrus (Mootral) or Green tea and oregano, and even using Ozone as a feedstock.

90 Good Food Institute 2021: State of the Industry Report; plant based meat, dairy, seafood and eggs.

91 Government investment in the opportunities of alternative proteins. What are other countries doing and how does Aotearoa New Zealand compare? Food HQ, Emerging Proteins NZ, AGMARDT Sept 2022

4. Circular Economy Opportunities In The Irish Agrifood Sector

Authors:
Andrew Keys | Iside Tacchinardi
Yasmina Lembachar

Credit: Shutterstock

Acknowledgements

Circle Economy would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Andrew Keys (Circle Economy), Iside Tacchinardi (Circle Economy), Yasmina Lembachar (Circle Economy)

Contributors

Marc de Wit (Circle Economy), Pau Ruiz (Circle Economy), Susan Alvarado Cummings (Circle Economy); Ana Birliga Sutherland (Circle Economy)

Reviewers:

Saskia Visser (EIT Climate KIC), Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC)

How to cite this report:

Circle Economy. (2022). *Circular economy opportunities in the Irish agrifood sector: A circular economy approach to building a sustainable and resilient agrifood system in Ireland.* Chapter 4 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Glossary of Terms

Carbon emissions	Carbon emissions refer to the greenhouse gases that are emitted and are expressed in terms of their equivalent warming potential to carbon dioxide (carbon dioxide equivalents (CO_2e)).
Food loss and waste	Food loss and waste encompass food lost and/or wasted at every step of the supply chain. 'Food loss' refers to the discarding of food resulting from decisions made and actions taken by stakeholders in the supply chain from post-harvest up to, but not including, food service and retail. 'Food waste' typically refers to food that is discarded due to the decisions and actions of distributors, retailers, food service providers and consumers.
Greenhouse gases	Greenhouse gases (GHGs) are gases that are capable of absorbing and re-radiating infrared radiation within the Earth's atmosphere. Common GHGs include carbon dioxide, methane and nitrous oxide.
Material footprint	Material footprint, also referred to as Raw Material Consumption (RMC), is the attribution of global material extraction to the domestic final demand of a country. In this sense, the material footprint represents the total volume of materials (in Raw Material Equivalents) embodied within the whole supply chain to meet final demand. The total material footprint, as referred to in this report, is the sum of the material footprints for biomass, fossil fuels, metal ores and non-metallic minerals. [Source]

Circular Economy Opportunities In The Irish Agrifood Sector

Food systems provide basic nutrition to almost 8 billion people on the planet. At the same time, they are one of the biggest global drivers of environmental damage, from climate change to biodiversity loss[1]. Already crossing several planetary boundaries[2], food systems contribute one-third of total greenhouse gas (GHG) emissions[3] and occupy nearly 40% of total landmass to grow crops, graze livestock and produce animal feed. [4]

In Ireland, this figure is even higher: 65% of the country's land—roughly 4.5 million hectares—is used for agricultural practices. Grassland accounts for 82% of this area, showing the dominance of livestock production in the country—particularly cattle and sheep.[5] Less than 2% of this is managed organically[6]—and ever-prevalent, intensive land use is a prime driver of biodiversity loss,[7] which has seen a 41% increase between 2012 and 2020.

The agrifood sector is Ireland's oldest and largest indigenous industry. It remains a substantial employer and contributor to the economy: it boasts a strong presence in communities across the country—especially in rural areas, and is one of the largest employers, with 164,400 people, representing 7.1% of total employment. Economically, the sector accounted for 7% of Gross National Income (GNI) in 2020 and represented 10% of exports by value. It is driven by its 137,500 farms, over 770,000 hectares of forest, over 2,000 fishing vessels and some 180 aquaculture sites. The sector experienced growth in the past decade, particularly in food manufacturing, with Irish food and drink exports being a major driving force.[8]

The agrifood sector, however, does not come without impact. Short-term perspectives in the sector have detrimental effects on soil health, ultimately leading to longer-term consequences such as reduced yields (as intensive monocultures lead to soil depletion in the long run), less nutritional food and less resilience to climate change. Grazing's prevalence also means that forest cover is relatively low, claiming just over one-tenth of Ireland's land as of 2017.[9] The government, however, aims to increase forest and woodland coverage to help in solving issues related to climate, biodiversity and housing in the coming decade.[10]

This chapter takes an international perspective to the circular economy approach, presenting insights that could aid Ireland's agrifood sector in transitioning to a more sustainable system. Section one introduces the concept of a circular economy in the context of agrifood systems, identifying three key pillars of circular food systems (1) Regenerative and, where appropriate, local food production, 2) low-impact and healthy diets and 3) designing waste out of food and food packaging). Sections two to four focus on each of these respective pillars—first identifying international best practices, then common barriers and, finally, relevant policy recommendations to overcome them, at both national and local levels. Section five applies previous chapters' international perspective to analyse the Irish agrifood system going forward. It identifies where strengths and gaps exist based on the nation's agrifood and environ-

mental strategies. Finally, Section six makes key recommendations for Ireland going forward, to fully embrace the concept of circular economy in its effort to create a truly sustainable and regenerative agrifood system.

4.1 A circular agrifood system: Key concepts, definitions, and benefits

The circular economy is an economic system where waste is designed out, everything is used at its highest possible value for as long as possible and natural systems are regenerated.[11] The concept of circularity closely mimics nature, where there is no waste: all materials have value and are used to sustain life in a myriad of ways. If we effectively deploy these strategies, we will ultimately require fewer materials to provide for similar societal needs.

The four strategies we can use to achieve these objectives, based on the work of Bocken et al. (2016), 12 are:

- **Narrow flows—Use less:** The amount of materials (including fossil fuels) used in the making of a product or in the delivery of a service are decreased. This is through circular design or increasing the usage rates of materials and products.
- **Slow flows—Use longer:** Resource use is optimised as the functional lifetime of goods is extended. Durable design, materials and service loops that extend life, such as repair and remanufacturing, both contribute to slowing rates of extraction and use.
- **Regenerate flows—Make clean:** Fossil fuels, pollutants and toxic materials are replaced with regenerative sources, thereby increasing and maintaining value in natural ecosystems.
- **Cycle flows—Use again:** The reuse of materials or products at end-of-life is optimised, facilitating a circular flow of resources. This is enhanced with improved collection and processing of materials and optimal cascading by creating value in each stage of reuse and recycling.

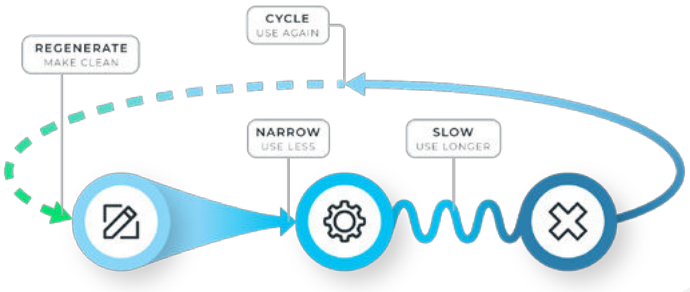


Figure 4.1:[92] *depicts the four flows to achieve circular objectives: narrow, slow, regenerate and cycle.*

92 Visual by Circle Economy, adapted from Konietzkoa & Bocken (2020).

The application of these strategies to the agrifood sector can be better contextualised by viewing them through the lens of three circular agrifood pillars, based on the work of the Ellen McArthur Foundation. These pillars, based on which the report will be organised by, are:

1. **Regenerative and, where appropriate, local food production:** In a circular economy, food is grown using regenerative practices that build soil health, promote plant diversity and avoid chemical and synthetic inputs. Where appropriate, food is produced as close as possible to where it is consumed.

Low-impact and healthy diets: In a circular economy, people can meet all of their nutritional needs through diets that do not exceed planetary boundaries. This means diets high in plant-based and whole foods and low in animal and processed foods. [14]

2. **Designing waste out of food and food packaging:** In a circular economy, food loss and waste are eliminated and, where prevention fails, redistributed for human consumption. The unavoidable byproducts of agrifood processes (for example, crop residues, manure and inedible parts of vegetables) are either returned to soils, fed to animals or processed into energy. In addition, unnecessary packaging is eliminated throughout the value chain and where it is necessary, is designed with circularity in mind.

When designed with just principles in mind, such circular food systems can deliver significant benefits to society, from climate action and opportunities for innovation to improved resilience, biodiversity and food security. [15] [16] The *Circularity Gap Report Scotland,* for example, found that circular agrifood strategies could reduce the country's material footprint by 10.8 million tonnes, and consumption-based GHG emissions by 4.2 million tonnes. [17] Meanwhile, recent research by SITRA found that by shifting to more alternative proteins and regenerative agriculture, and reducing food waste by half, biodiversity loss could be halted by 2035. [18]

4.2 Regenerative and, where appropriate, local food production

Industrial farms typically specialise in the production of one or two varieties of crops or in the intensive farming of animals, and often rely on monocropping techniques, synthetic fertilisers, herbicides and pesticides, as well as operations such as tilling and mechanical weeding or harvesting. These practices, while helpful to maximise productivity and yields in the short term, deplete soils of their nutrients, threaten pollinators, pollute groundwaters and air, and are energy-intensive. [19] Regenerative agriculture aims to reverse these trends by taking a systems approach, and focuses on restoring, maintaining and building soil health, promoting plant diversity (**regenerate)**, minimising chemical and synthetic inputs[20] (**narrow**) and closing biological nutrient cycles (**cycle**). In doing so, regenerative farming aims to increase biodiversity, resilience and yields, improve watersheds, enhance ecosystem services, capture carbon and promote the health and well-being of local communities. [21] Naturally, trade-offs are required depending on which outcomes are deemed more favourable than others—for example, how to balance GHG emissions reduction with biodiversity conversation whilst conducting reforestation—and so such a transition requires careful planning and management.

A regenerative and circular food system also prioritises local food production where appropriate—not only to reduce the impacts associated with transportation and keeping food fresh, but also to improve access to food and build community.[22] Local food production is not always the most environmentally sustainable option, however, as the food production system involves many more factors than so-called 'food miles' alone to provide an accurate assessment of sustainability.[23] While this section mostly focuses on regenerative agriculture practices, the transition to local food systems also faces similar challenges and can benefit from similar interventions at the national and local levels.

Best practices

Agrifood supply chain	Best practices
Food production	**Regenerative agriculture** aims to:[24] • Maintain soil cover • Build soil health • Sequester carbon • Rely more on biological nutrient cycles, reducing reliance on mineral fertilisers and avoiding pestiwcides • Foster plant diversity • Encourage water percolation Key agronomic principles and **best practices** involve:[25] • (Multi-species) cover crops • Minimising tillage (no- or low-tillage) • Biochar (contextualisation is key to use this practice, see footnote)[93] • Compost and other green and animal manures • Agroforestry (incorporation and mix of forest areas with crop and staple crop cultivations[26]) and silvopasture (when animals are also part of the landscape) • Diverse crop rotations • Rotational or holistic grazing Regenerative agriculture practices share many principles with organic farming, permaculture and agroecology. To share the costs of the transition, farmers can purchase inputs needed in groups[27] and pool equipment services. Cooperatives or local farmers' associations can be key platforms for this.

93 The effectiveness of utilising biochar to increase nutrient use efficiency and the capacity of the soil to retain water, highly depends on base-line quality of the soil (for example, biochar has proven very effective on nutrient-poor soils but not as much on already nutrient-rich soils). Moreover, the quality of biochar and its material composition are key for its employability. If biochar contains contaminants and toxic materials, such as heavy metals, its application can be detrimental to soil fertility. For more information on the topic please consult the following sources:

Hussain, M., Farooq, M., Nawaz, Nawaz, A., Al-Sadi, M., Solaiman, M., Alghamdi, S., Ammara, U., Sik Ok, Y., & Siddique, M. (2017). Biochar for crop production: potential benefits and risks. Journal of Soils and Sediments 17, 685–716. doi: 10.1007/s11368-016-1360-2

El-Naggar, A., El-Naggar, H. A., Shaheen, S. M., Sarkar, B., Chang, S. X., Tsang, D., & Rinklebe, J. (2019). Biochar composition-dependent impacts on soil nutrient release, carbon mineralization, and potential environmental risk: A review. Journal of Environmental Management, 241, 458-467. doi:10.1016/j.jenvman.2019.02.044

Agricultural production

Improved nutrient management for 250 dairy farmers[28]

Photo by Daniel Quinceno, retrieved from Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, REGENERATE | MAKE CLEAN

Livestock generate organic waste compounds such as phosphorus and nitrogen that leak into the environment, polluting ground and surface waters (as well as soil and air). This was the case in the Dutch province of Gelderland, which raised concerns about the quality of drinking water in the province.

Vruchtbare Kringloop Achterhoek (VKA) is a collaborative initiative of farmers, water suppliers, the water board *Waterschap Rijn en IJssel*, the province of Gelderland and multinational companies in the Netherlands. To tackle the problem, VKA tailored livestock diets to provide the exact quantity of nutrients they need and increased the yields of feed crops as a means to absorb more nutrients in the soil and hence reduce the overall surplus of minerals.

The project resulted in the elimination of phosphorus surpluses on the farms, as well as a 9% reduction of the nitrogen surplus in the soil. Overall, 25% of the companies involved were able to use 100% of their phosphorus and 48% of their nitrogen—meaning more farmers provided an optimal amount of nutrients to their feed crops without significantly exceeding a level that pollutes the soil. Subsequently, farmers registered an overall increase in milk production and lowered costs for the disposal of manure, as most of the manure produced was used on-farm.

More information can be found on the Vruchtbare Kringloop Achterhoek website.

Agricultural production & Trade

No-till & crop rotation in Ghana and Sierra Leone [29]

Photo by Annie Sprott from : Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, REGENERATE | MAKE CLEAN

Smallholder subsistence farmers in West Africa have faced difficulties in terms of having stable and safe access to the market. At the same time, they have struggled to increase yields and were heavily reliant on synthetic fertilisers.

The Warc group established a 'bundle of buyers' approach to ensure farmers' safe access to markets, by linking them to different purchasers across the value chain. Warc manages three farms and works with over 10,000 smallholder farmers producing rice, maize, sorghum and soy. Each farmer is provided with regenerative agriculture inputs and then paid for their products. Warc aggregates the produce of the farmers and sells it to large grain buyers.

This has allowed farmers to maintain predictable selling prices for their products. In addition, the farmers in the project have switched to regenerative agriculture, applying no-till farming methods and thus minimising synthetic inputs.

More information can be found on the Warc Africa website.

Barriers and policy recommendations

Transitioning from linear agrifood chains to regenerative and circular value chains is complex and challenging. Some of the barriers inhibiting this transition are present at the farm level, such as having the capital to finance such a transition, acquiring the relevant knowledge and experience for implementation, and accessing retail markets. The following section delves deeper into some of the barriers faced by farmers today.

Farmers lack the financial resources required to invest in the transition and need support to minimise risks to their profitability

Transitioning from mainstream industrial farming to regenerative agriculture requires time and financial investment in knowledge, labour, infrastructure and tools (for example, systems to capture rainwater or to manage bulk transportation of manure, equipment for zero tillage, etcetera). [30] These investments, when done right, can pay off in the long-term (for example, eliminating input costs, increasing selling prices on the market, and securing soil fertility and land yields). [31] However, farmers tend to be risk-averse, face social pressure to continue with tried-and-tested methods of farming used over generations, or lack the financial capital to both undergo such long-term financial investments and have enough of a financial buffer to compensate if the expected benefits are lower than expected. These factors thus limit the adoption of regenerative practices. [32 33 34]

Actor	Enabling policy and action recommendation
National Government [35 36 37]	• Provide direct financial support, such as soft loans, long-term loans that enable long-term planning (considering variation in annual yields and revenues),[94] microfinancing lending (grouping smallholders in one loan package), debt financing and insurance schemes that protect against reduced yields early in the transition to a regenerative system. • Create an enabling environment for regenerative agriculture through supportive fiscal frameworks such as tax breaks and subsidies. Incubators and investment programmes that promote regenerative principles, such as soil health, may also be implemented.
Local Government [38] [39 40]	Local governments may seek to: • Prioritise regenerative, local food in public procurement strategies. This can economically benefit local farmers, create more stable income, stimulate employment in the sector and reduce reliance on imports. • Allocate a share of local taxes to be used to support regenerative agriculture practices and stimulate local food production.

94 Financing through loans should be treated with some caution given that the outcomes of regenerative agriculture may not always be predictable, especially in the initial years. As experience is gained with regenerative practices, outcomes should become more predictable and loans can be utilised on to a greater extent.

Lack of policy instruments supporting regenerative agriculture & strong lobbying power of agrifood industry

The second barrier to implementing regenerative practices is a lack of support from targeted governmental policies and regulations. Governments do not tend to politically prioritise regenerative agriculture, and tailor their incentives to conventional agricultural practices such as monocultures and the use of chemical fertilisers.[41] Although some government policies do promote some aspects of regenerative farming, they still often fail to recognise the concept as a whole, inhibiting widespread adoption.[42] Moreover, agrifood industries around the world are lobbying against changes or possible threats to their businesses, such as reducing the use of chemical fertilisers.[43,44] For the government to make changes, it must collaborate—but not compromise—with the agrifood industry, in order to make the systemic changes necessary.

Actor	Enabling policy and action recommendation
National Government[45,46]	• Generate a long term vision on the future 'normal' agricultural production. • Create standards & certifications for regenerative agriculture to allow farmers to access market premiums for sustainable farming. • Offer free soil health testing and data collection. • Establish regenerative agriculture criteria for the public procurement of food services • Establish standards and regulations for publicly-owned land to be converted to regenerative farms.
Local Government[47]	• Establish regenerative agriculture criteria for the public procurement of food services. • As with national governments, establish standards & regulations for publicly-owned land to be converted to regenerative farms. Make the most of underused spaces by supporting regenerative farming on, for example, lots placed on unused rooftops and in vacant buildings. • Remove regulatory barriers to promote regenerative agriculture locally. This can be done through enabling land-use regulations, and by protecting areas for conservation projects, permitting municipal composting, enabling and facilitating the direct sale of local produce at markets, and directing leasing land to regenerative farmers. Incentivise (financially) and facilitate (legally) the creation of food cooperatives, community supported agriculture and local initiatives designed on the principles of the commons—which all contribute to boosting local sustainable food production. • Set targets and implement policies aimed at restoring groundwater bodies, polluted agricultural land and enriching seed variety.

Lack of knowledge and experience in regenerative practices and difficulties accessing retailing and selling infrastructure

The technologies and infrastructures available today mostly focus on conventional/industrial practices rather than regenerative practices.[95] The knowledge and experience required to implement regenerative activities are often missing—particularly as they introduce more complexity in both space (by introducing companion or cover crops), and time (more diverse rotations).[96] Since retailers and supermarkets typically prefer large and same-product suppliers throughout the whole year, regenerative food producers can also struggle to meet these demands (as they perform seasonal and rotational production) and therefore struggle to utilise the retailing and selling infrastructures in place.[97]

Actor	Enabling policy and action
National Government[51 52]	• Subsidise the technological inputs necessary for the transition to regenerative agriculture. • Invest in training and knowledge-exchange platforms about regenerative agriculture for farmers to overcome the short-term planning horizon. • Invest in infrastructure to create additional markets for regenerative products and inputs.
Local Government[53 54 55 56]	• Create innovation incubators to test regenerative agriculture concepts and business models. • Collaborate with civil society and research institutes to collect data that can be published to facilitate the development of new tools to enable farmers to apply regenerative practices. • Facilitate training programmes to equip people with the skills and knowledge required for farms to transition to regenerative agriculture practices and to meet local skills shortages that may be needed to make this transition. • Provide infrastructure and equipment, as well as market access, by agreeing to purchase half of the harvest from regenerative farms. • Support the repair of cold chain items and food storage infrastructure • Allow the reuse of vacant buildings for food production and processing. • Enable farmers to have better access to retail markets by providing small producers with greater access to consumers. Create, facilitate and support initiatives such as farmers' markets and local food festivals to both raise awareness for local, sustainable produce as well as boost local farmers' income.

95 Circle Economy. (2021). Climate change mitigation through the circular economy. Retrieved from: Circle Economy website

96 SYSTEMIQ. (2020). Regenerating Europe's soils: making the economics work. Retrieved from: SYSTEMIQ website

97 Anderson, C. R., Bruil, J., Chappell, M. J., Kiss, C. & Pimbert, M. P. (2019). From transition to domains of transformation: getting to sustainable and just food systems through agroecology. Sustainability, 11(19), Article 19. doi:10.3390/su11195272

National Government

Healthy Soils Programme (California, USA)[57]

Photo by Crusenho Agus Hennihuno, retrieved from Pexels

STRATEGIES EMPLOYED: REGENERATE | MAKE CLEAN

In California, farmers who wished to shift toward regenerative agriculture faced economic barriers to do so. They often lacked financial capital or were reluctant to make long-term investments in the knowledge and infrastructure needed to transition. Additionally, governments did not have financial instruments (for example, soft loans, grants or subsidies) in place to support farmers in this transition.

The Healthy Soils Programme (HSP) is a state-level programme in California. It remunerates farmers who use practices that improve soil health and mitigate climate change (through carbon sequestration, for example). Now, farmers are paid per acre in which they implement regenerative practices, such as mulching, cover cropping, composting, and no/reduced till. In 2020, the funding allocated was at its highest, reaching €26.7 million (US$28 million).

As a result of this programme, the number of farmers adopting regenerative practices increased notably in California. 2020 saw a peak in the number of applicants and funds requested through the HSP—showing farmers' rising interest in shifting towards regenerative agriculture.

More information can be found on the California Department of Food and Agriculture website.

4.3 Low-impact and healthy diets

Our diets have a huge influence on agrifood systems. What we consume, how much we consume and where our food comes from all influence the impact we have on the environment and those who work in the entire agrifood value chain. Cattle farming and livestock farming are generally more resource-intensive, due to the vast quantity of animal feed required, compared to crop production meant for direct human consumption. In our current linear system, 77 million tonnes of plant protein is fed to livestock with a return of 58 million tonnes of animal protein—and forests, wetlands and other natural habitats are often converted to pasture land to feed crops such as soy and corn.[58] More than two-thirds of deforestation across the globe can be attributed to animal feed production.[59] Accordingly, a circular economy promotes the consumption of foods with a low impact on the environment. Shifting towards a diet with more fruit and vegetables and less animal protein is one of the cornerstones of a lower-impact diet. This would allow us to **narrow** material flows, as diets would shift towards less resource-intensive food, and **regenerate** flows, as the products of regenerative agriculture could become first-choice for consumers if well-promoted. According to the EAT-Lancet Commision on Food, Planet and Health, diets that are mainly based on plants (vegetables, fruits, grains and plant-based proteins) are highly nutritious and optimal for human health.[60]

Best practices

Agrifood supply chain	Best practices
Food production	• Meat producers can shift away from intensive livestock farming and move towards smaller-scale meat production or different activities like agritourism, recreation and hospitality activities that may be economically attractive to farmers.[61] • Food companies that purchase large quantities of beef can change their suppliers, turning to beef producers that use improved and non-emissions-intensive practices, such as: - improved feeding practices (adopting more digestible feed); - enhanced manure management (for example, through frequent manure removal from barns, the use of manure as soil fertiliser and the use of manure to produce biogas via anaerobic digesters); - rotational grazing and silvopasture (the integration of trees and grazing livestock on the same land).[62,63] • Farmers and meat producers can engage constructively with civil society, academia and the government regarding policy proposals that impact them, for example, policies aimed at cutting back meat production and consumption.[64]
Fast-moving consumer goods companies (FMCGs) and retailers[65]	• Fast-moving consumer goods companies can **reshape product portfolios, recipes and menus** to enhance the sustainability of their offerings (for example, shifting to no palm oil use, vegetarian and vegan options and locally sourced and organic/regenerative ingredients).[66] • Food production and processing companies should invest in prioritising plant-based foods—including a variety of legumes, vegetables, fruits, seeds, and other alternative proteins (for example, insects), with respect to the seasonality and provenance of these ingredients. These products must be made appealing to consumers to be competitive on the market, especially compared to their meat-based alternatives. For example, companies can incorporate more plant-based foods in ready meals, and innovate to create products that resemble meat-based or dairy products.[67] • Retailers can use **consumer design** to shift consumer choices towards lower-impact, healthier diets. They can use findings from research in behavioural science to influence consumer choices in both physical and online retail outlets. These tactics have proven effective for online platforms. • Together with food brands, retailers can also **collect and communicate data on food impacts** to better inform consumers about the impact of their choices. Decision-making as a consumer can be extremely complex, even when the data is available: it requires considering factors such as locality, seasonality and production methods. Therefore, the communication of the overall environmental impacts of a food product should be clear and allow products to be comparable to enable informed decisions.[68]

Food retail and provisioning

World Resources Institute (WRI): Language of sustainable diets[69]


Credit : Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, REGENERATE | MAKE CLEAN

Consumer choices are important for the transition to a sustainable agrifood sector. However, it is difficult to change eating habits and incentivise people to consume more sustainably.

Language can shift consumers' perspective on food. A study by the World Resources Institute explored which language describing plant-based menu items is most effective at encouraging consumers to select these options. This was achieved by conducting a field experiment across a UK-based chain of cafés.

The authors concluded that language does indeed have an effect on consumer choices. Terms such as 'Meat-free' and 'Vegetarian' highlight the lack of meat in the dish—and were found to be a deterrent. Instead, using terms such as 'Field-grown' or 'Garden', or with language that emphasises flavour, increased the proportion of people who chose the target vegetarian dishes.

More information can be found on the World Resources Institute website.

Food retail and provisioning

Foundation Earth: Ecolabelling

Photo by Anna Shvets, retrieved from: Pexels

STRATEGIES EMPLOYED: NARROW | USE LESS, REGENERATE | MAKE CLEAN

Consumer choices are important for the transition to a sustainable agrifood sector. However, food packaging labels are often not communicating products' environmental impacts. There are 147 distinct labelling methods throughout Europe, which is confusing to both consumers and manufacturers.

By developing a single, straightforward and systematised environmental label, Foundation Earth hopes to empower customers to compare products and make educated decisions that are better for the environment.

Several companies, including Nestlé, Finnebrogue, Greencore, The Meatless Farm, and Marks and Spencer are participating in the pilot initiative to implement the labels on their product packaging. [1] [2]

More information can be found on the Foundation Earth website.

1 Steer-Stephenson, C. (2022, 23 August). Supermarket eco-labels to boost sustainability transparency. Retrieved from: Sustainability Mag website

2 Just Food. (2021, 27 June). Food giants sign up to new Foundation Earth eco-labelling scheme. Retrieved from: Just Food website

Barriers and policy recommendations

Changing consumers' behaviour in favour of more sustainable diets is not without challenges. Lower-impact food options can sometimes be more expensive than their high-impact counterparts, cultural attachments can outweigh sustainability factors and there is often a lack of sufficient knowledge and awareness regarding various foods' environmental impacts.

Reluctance to change diets and low consumer knowledge of food impacts

Food is deeply ingrained in culture and forms a part of people's identity. Therefore, external factors that aim to change diets can face strong resistance. A shift away from resource-intensive foods, such as meat, would be particularly challenging to instigate in the Irish context, where livestock rearing—and subsequently meat consumption—is deeply rooted in the culture. [72]

Despite a growing concern for food sustainability, the general public still has little knowledge about the impact different food choices have on the environment. Some consumers seem to be sceptical of the effects that meat production has on the environment. Accordingly, misconceptions about the environmental impacts of food can also be an obstacle for behaviour change. [73]

Actor	Enabling policy and action recommendation
National Government [74] [75] [76]	• Raise awareness among civil society. This could be done by running information campaigns on publicly-owned media, and integrating lessons and information about the impact of food systems in school and university curricula. Food labelling that reflects the 'true prices' of food may also raise awareness while influencing consumer choices. • Update national dietary guidelines and public procurement guidelines to favour healthy and low-impact diets.
Local Government [77]	• Run consumer awareness campaigns to help consumers understand the impact of their food choices. [78] This can be done, for example, through online platforms comprising different tools such as meal plans, recipes and nutrition information. Various mediums—from printed resources to social media and mass media—can be used to spread the word.

Price competitiveness of low-impact food

While plant-based foods may be cheaper than animal products, local, organic and seasonal products are typically more expensive than mainstream agrifood products, the prices of which do not include environmental externalities. Hence, the price difference between these two types of products constitutes a competitive disadvantage for regenerative farmers, who then struggle to find distribution channels. [79] In Ireland, farms are heavily dependent on subsidies to survive, with over 56% of family farm income coming from subsidies in 2017. [80] This has the potential to create market distortion, where true cost of animal-based protein is not reflected and therefore less resource-intensive food production may be less competitive. [81]

Actor	Enabling policy and action recommendation
National Government 82	Ensure that healthy, low-impact foods remain cost-competitive with high-impact alternatives through price regulation measures: for example, tax breaks and/or subsidised prices for low-impact foods.
Local Government	Not applicable

Local Government

Circular catering services (Plavinu, Latvia)[83]


Credit: Shutterstock.

STRATEGIES EMPLOYED: NARROW | USE LESS, SLOW | USE LONGER, REGENERATE | MAKE CLEAN

Incorporating circular principles into public procurement policies can help stimulate local food production that's produced and retailed sustainably. The municipality of Plavinu, Latvia aims to incorporate circular principles in the catering service of its local schools. In addition to sustainability, the strategy also addresses nutrition and health concerns. It bans the use of disposable plastic packaging, while requiring the use of seasonal produce and setting minimum levels for organic production of dairy, for example. Under the strategy, service providers are also required to sort waste according to waste managers' instructions.

It is expected that the initiative will significantly reduce packaging and food waste. The latter can be achieved by educating pupils, adjusting menus and allowing more flexibility with portion size. The shift towards more organic sources of milk is expected to reduce the use of pesticides for animal feed as well as increase animal welfare standards.

More information can be found on the European Circular Economy Stakeholder Platform website.

Credit: Shutterstock

4.4 Designing waste out of food and food packaging.

Food loss and waste (FLW) occurs throughout the value chain, from production and processing, all the way to consumption. In a circular economy, FLW is minimised as much as possible—which plays a great role in **narrowing** circles as less resources are needed to satisfy the population's needs.

Part of the waste produced throughout the agrifood value chain is unavoidable, such as animal manure, crop residues or inedible parts of fruit and vegetables (like pits and peels). In a circular economy, the value of these byproducts is maintained as much as possible by returning them to the soil (for example, by feeding them to animals, or through the creation of organic fertilisers), or by transforming them into biogas for energy production—both **cycling** material flows.

Similarly, packaging—and packaging waste—is also found throughout the agrifood value chain, stemming from a range of applications, from baling hay to protecting and preserving food and vegetables. A circular packaging system reduces material use (**narrowing** flows), provided that it doesn't significantly reduce the lifespan of the product, and is designed to maximise reuse and recycling potential (**slowing** and **cycling**). The use of **regenerative** (bio-based) and secondary materials are favoured for packaging—which reduces demand for **non-regenerative** materials such as fossil fuels, pollutants and toxic materials. However, it is important to carefully consider the production of biomass explicitly for packaging: often, conflicts exist in terms of competing land for food production and it's difficult to ensure regenerative practices are carried out, just as with food production. Therefore, byproducts and waste from biomass are generally favoured for producing bio-based packaging—along with designing packaging for biodegradability or recycling.

Best practices

Food loss and waste

Agrifood supply chain	Best practices
Food production	• Improve harvesting practices through well timed harvesting and the use of harvesting equipment that maximises yields while minimising crop damage. • Engage customers by being transparent about how quality specifications are changing to enable more of what is harvested to be sold. • Identify opportunities for selling or donating surplus crops that are typically unmarketable (due to bruises, non-compliance with quality standards and poor harvesting techniques) such as selling to secondary surplus markets, value added processing into other products (such as for bio-based packaging) or donation to food banks. [84] [85]
Food storage, transport & trade	• Facilitate **shorter food supply chains**, which reduce transportation costs and their associated GHG emissions. This localisation often relies on community-supported agriculture models and direct selling by farmers to customers. [86] • Improve **equipment to reduce post-harvest losses,** and support **cold storage facilities and cold transport**. These activities require more energy use, which may increase GHG emissions. Nevertheless, the benefits in terms of FLW reduction outweigh the required energy increase, especially if renewable energy is used. [87]
Food processing & transformation	• Implement **industrial symbiosis** in food processing facilities. This involves using waste or by-products from one process in another process, either internally or with other food processing facilities. The food processing and transformation stage has great potential to utilise industrial symbiosis due to the large volumes of organic residual materials, waste water and packaging generated. [88] Strategically locating food processing facilities in proximity to each other can facilitate and encourage the exchange of such materials, whilst mutually benefitting multiple stakeholders.
Retail and consumption	• To prevent food waste, retailers and other consumer-facing food businesses can use **technology** to monitor and identify preventable causes of food waste. • To decrease food waste during distribution (for example, at wholesale markets, retail markets and restaurants), new platforms can be created to **facilitate the donation of unsold goods**. [89] Nevertheless, food donations to food banks and charity organisations are short-lived solutions to food poverty. Accordingly, they should not be perceived as solutions to the structural and root causes of food poverty. [90] • Food retailers can collaborate with businesses and start-ups that aim to create value from food that would otherwise become waste. - Supermarkets can allocate some of their shelves for the sale of food that is produced using their food waste (for example, soup produced with waste vegetables and cookies made with stale bread). This is exemplified by Dutch initiative 'Verspilling is Verrukelijk' (Waste is Delicious), which links different supermarkets with 18 Dutch food companies that make products out of food waste. • Supermarkets, restaurants, bakeries and catering services can collaborate with entrepreneurs that wish to sell and distribute end-of-the-day food waste. 'To Good to Go', for example, is an app and system that allows retailers to sell their leftovers/food waste to consumers. • Supermarkets can reduce food waste by creating in-store **price promotions for perishable goods**. • Supermarkets can use their influence to support FLW prevention upstream and downstream. For example, they can conduct **consumer education campaigns** (providing clarity about different food labels, giving tips on how to improve food storage and extend the shelf-life of fresh food, make recipes with leftover food and decrease portion sizes). This can be done employing pamphlets, in-store displays and online information. [91] They can also work together with manufacturers to **update food expiration labels** so as to avoid confusion and enhance clarity, for example, by explaining the difference between various date labels, such as 'sell by', 'use by', 'best before', or, ideally, limiting labelling to food safety indications such as 'use by'. Further measures include **whole crop purchasing**, where entire crops are procured, and then the lower quality food is incorporated into processed product lines; **improved forecasting** of food demands; **marketing of seasonal produce** and **relaxing cosmetic standards** on standard food product ranges, and introducing new product lines with lower specifications. [92]

Food retail

Albert Heijn's Food Waste Mission 2021 [93]

Photo by Sydney Rae, retrieved from: Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, SLOW | USE LONGER

In the Netherlands, the food waste rate is 2 billion kilograms per year. At the supermarket level, the fruits, vegetables and bakery departments generate the majority of this waste—but much of it can be avoided in the first place. In 2018, Albert Heijn, together with other Dutch supermarkets, jointly set the target of halving food waste by 2030 compared to 2015 levels. Accordingly, Albert Heijn designed and implemented different strategies:

i. A smart ordering system that adjusts food orders/the supply automatically based on expected sales;
ii. Using an app to determine the amount of fresh bread to be baked at different hours;
iii. The 'Bread of yesterday' programme—which makes bread from the day before extra affordable, selling a bag of bread buns for 50 cents;
iv. Putting a 35% discount sticker on products that are approaching their shelf-life-end while gathering them together in a fridge at the centre of the shop, as the discounted products of the day;
v. Donating the remaining food waste to food banks.

These strategies have reduced the amount of food waste generated by Albert Heijn each year since 2018 by 21%—falling from 6.2 to 4.9 tonnes of food waste per million euros of food sold.

More information can be found on the Albert Heijn website.

Packaging waste

Agrifood supply chain	Best practices
Food processing and transformation	• Food processors should aim to **reduce the use of packaging, where appropriate, and where necessary use bio-based, recycled and reusable packaging.** Packaging plays a large role within the food processing stage, from transporting primary food and feedstocks to the processing plant, to packaging final food products for further transportation and retailing. • Food brands can adopt circular strategies to reduce food packaging by cutting down the use of virgin materials, unnecessary packaging and non-recyclable plastics, whilst opting for mono-material designs and packaging made from from biomass byproducts. [94] [95] • Packaging waste can be reduced through collaboration between retailers and food brands to pilot zero or reusable packaging delivery models.
Retail and consumption	• Food retailers can adopt business models based on reusable and durable alternatives to single-use packaging, for example through refillable aisles. • Food retailers can establish take-back programmes for consumer packaging waste that can then be sorted and sold to recycling facilities.

Food retail & provisioning

ReCIRCLE—a solution to plastic waste in the food sector

Photo by Agenlaku Indonesia, retrieved from: Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, SLOW | USE LONGER, REGENERATE | MAKE CLEAN, CYCLE | USE AGAIN

Restaurants generate high volumes of plastic waste: the amount of waste is sometimes unpreventable. The company ReCIRCLE aims to replace single-use plastic, common in the food sector, with a reusable alternative. ReCIRCLE products are intended to be used, refilled and washed hundreds of times and at their end of life, they can be returned to retailers to be recycled, and the consumer receives a replacement or gets their money back. The company is targeting restaurants, allowing them to reduce plastic, encourage excess food to be rescued, save money and increase customer loyalty. In addition, the company also offers a rental service catered to the meal service industry to remove any high start-up costs, whilst allowing them to reduce their waste.

By working with the local communities and schools, ReCIRCLE aims to set an example of how individuals and the hospitality sector can cut single-use waste, disposal costs and GHG emissions.[96] Through adoption across Europe, the company claimed to have saved over 14 million single-use packages in 2021, translating to 1.4 thousand tonnes of avoided GHG emissions.[97]

More information can be found on the ReCIRCLE website.

Barriers and policy recommendations

Tackling food and food packaging waste requires interventions along the value chain, from the design stage until the time food products are consumed and disposed of. A lack of incentives and penalties to stimulate waste reduction, coupled with a general lack of infrastructure to support recycling efforts, makes this more challenging. A number of trade-offs also need to be managed when it comes to reducing food packaging, as packaging often contributes to maintaining food safety. The design and adoption of waste-free packaging and packaging from recycled or bio-materials must take food safety standards and measures into account.

Lack of funding for—and data on—food loss and waste reduction

There is an overall lack of funding at all levels for measures that can reduce food loss and waste. This is partially due to the fact that there is little data available quantifying the impact of minimising food waste.[98]

Actor	Enabling policy and action
National and Local Governments [99 100 101 102 103]	• Invest in collecting and monitoring food waste data to quantify the economic value lying in this field. • Invest and increase funding in research to identify hotspots for action to tackle food waste and loss. • Invest in research that addresses post-harvest losses and deliver incentives for farmers to adopt post-harvest technologies. This could mean, for example, subsidies for purchasing post-harvest technologies, zero taxes on the import of these technologies and incentives to manufacture post-harvest technologies locally). • Engage in public-private partnerships (for example, with national agriculture and environmental agencies, research institutes and food business) to address and reduce food loss and waste.

Lack of policies and laws that promote and subsidise activities that counter food waste and loss

There is often a lack of incentives—positive or negative—for businesses and consumers to reduce food waste and loss. Therefore, the disposal of valuable food waste continues to go on without any repercussions. Strict food safety regulations, for example, mean that businesses are often required to throw food away before it's gone off.[104]

Actor	Enabling policy and action
National Government [105] [106] [107] [108]	• Abolish regulatory obstacles (for example, tax breaks and liability limitations) to redistribution and donation of unsold food (which is still safe to eat) to food banks, charities, and people in need. Thus, facilitate the sharing of food that is imperfect or to be wasted. • Ban commercials that stimulate people to buy more of a product, for example, buy-one-get-one-free deals. These can lead to people wasting more due to overbuying and obesity due to overeating. • Include the private sector in the design of roadmaps, strategies, targets and policies that tackle food waste and loss. • Create policies that put a halt to unfair and waste-producing trading operations (for example, last-minute cancellations of orders and retroactive contract changes). • Develop laws binding large companies to mandatorily report and measure their food waste. • Develop policies that aim at the standardisation of food labelling—to prevent consumer confusion about food safety—and clarify the meaning of date labels to consumers.
Local Government [109] [110]	• Disincentivise the landfilling of food waste by increasing disposal fees, and favouring the development of alternative business models and better waste management practices that aim to eliminate the production of waste and retain more value from what is produced. • Implement mandatory organic waste collection systems for restaurants, supermarkets and households; for example, through a pay-as-you-throw model that incentivises organic waste separation.

Lack of infrastructure and markets for surplus food

Farmers often do not have the financial capital to invest in infrastructure, such as value-added and processing facilities, that can turn food waste into processed and sellable products. At the same time, a market (with relative infrastructure linking producers and consumers) for surplus foods is lacking—especially for food that is rejected at purchase due to cosmetic standards and close-to-expiry dates.

Actor	Enabling policy and action
National Government [111] [112]	• Provide funding to allow farmers to construct value-added facilities and thus increase their processing capacity. • Support startups that match residual food with demand; through, for example, subsidies, grants, the financing of incubator programmes, provision of office spaces and workshops.
Local Government [113] [114]	• Invest in supplying food waste processing infrastructure, such as composting, anaerobic digestion and systems, as well as processes to convert municipal food waste into agricultural inputs such as fertiliser or animal feed. • Invest in optimising cold chains and refrigerators and eliminating unnecessary ones.

Food waste is seen as socially acceptable

Established habits—often embedded in culture—play a great role in upholding the status quo and social acceptance around food waste, especially at the household level. [115] In high-income countries, food waste is often seen as socially acceptable. A lack of knowledge and awareness about food waste and its detrimental effects contribute to this. [116] For 'zero food waste' to become the established norm and habit, social norms must first be reversed.

Actor	Enabling policy and action
National Government [117,118]	• Roll out consumer education campaigns on food waste at the household level This could include information on how to better store food at home, plan for groceries or cook with left-overs, while highlighting the financial benefits of reducing food waste. • Integrate lessons on food waste reduction as a mandatory part of school curricula.
Local Government [119]	• Carry out social norms interventions. First, descriptive norms messaging can be done by communicating what the rest of the community is doing to tackle food waste and how many people in the neighbourhood are acting on this issue—for example, '80% of Americans are making an effort to reduce the amount of food they waste every day', or 'Join your neighbours in reducing food waste!'. Second, injunctive norms messaging communicates what other people deem to be the right behaviour in a given context. This may entail telling people that their neighbours highly disapprove of food waste. For example, '83% of Amsterdam residents agree that wasting food is a big problem in the Netherlands' or '80% believe that wasting food is highly detrimental to the environment'.

Incentives to transition away from single-use and complex packaging are lacking

At present, there is a lack of regulation and standards to discourage the use of single-use packaging; a lack of public and private funding; insufficient collection and recycling infrastructure (especially for complex packaging); and a lack of consumer demand. [120,121] In addition, there are a number of risks involved in transitioning product lines towards possessing more circular packaging principles, even if the aspiration is there. [122] Changing packaging typically requires an upfront capital cost to implement new technology, and so there is more incentive to lightweight packaging rather than change the format. Despite a growing shift in consumer views on reducing the use of single-use packaging, new types of packaging can still lead to negative perceptions—that the food product is of lower quality, for example. In addition, new forms of packaging can also influence retailers' positioning of products, which can have a negative impact for the food processor. Therefore, a lack of collaboration between food processors and retailers, and typically short-term relationships, can increase the risk of product sales dropping.

Actor	Enabling policy and action
National Government [123,124]	• Set national consumption reduction targets (to reduce the production and consumption of single-use plastic packaging) and objectives for reuse and recycling. Collaborate with local governments on this, as they are key to understanding how to implement national regulations on reuse at the regional/local scale. • Impose bans on single-use plastic packaging. • Restrict the use of multi-material packaging to enhance recycling potential. • Promote the use of secondary and bio-based inputs, as well as reuse alternatives through financial incentives (such as subsidies and tax breaks) and facilitate innovation programmes for new products and business models. • Create clear standards (for example, requiring a mandatory percentage of recycled plastic for food and beverage containers). Allow enough time for producers to adjust their practices according to the new product design regulations. • Implement extended producer responsibility across a wide range of packaging products.
Local Government [125,126]	• Create awareness raising and educational campaigns that tackle single-use plastic (beverages and food containers) at the household level. • Incentivise a take-back and reuse system for food and beverage containers (for example, reusable cups) in local bars, restaurants, festivals and public canteens/catering services.

Local Government

Love Food, Hate Waste (Multiple cities in the UK) [127]

Photo courtesy of WRAP

STRATEGIES EMPLOYED: NARROW | USE LESS

In high-income countries, food waste at the consumption level amounts to roughly 79 kilograms per person per year on average.[128] In the UK, 70% of all the food that is wasted is wasted by citizens in their own homes: 4.5 million tonnes of food that could have been eaten, thrown away every year.

To raise awareness for the issue and to provide citizens with tools to reduce their own food waste, multiple local authorities in the UK have run 'Love Food, Hate Waste' campaigns—a tried and tested citizen-facing campaign model developed by WRAP. Love Food, Hate Waste provides municipalities with resources and guidance on how to run citizen-facing communications about food waste prevention (for example, through local public relations, road shows and cookery demonstrations). Between 2007 and 2018, past campaigns have successfully helped deliver a 15% decrease in the amount of food wasted by UK households. [129]

More information can be found on the WRAP website.

National Government

Dansk Retursystem (Denmark) [130]

Photo by Nick Fewings, retrieved from: Unsplash

STRATEGIES EMPLOYED: NARROW | USE LESS, CYCLE | USE AGAIN

In Denmark, returning empty standardised glass bottles from consumers back to breweries has been a common practice since the 1890s. In the 1920s and 1930s, this deposit system spread—with unified beer bottles and crates—to all breweries in the country. In the 1990s, however, with the emergence of many different plastic containers and cans for beverages, it became challenging for retailers to handle and sort this variety of packaging. Waste from plastic packaging also emerged as an environmental problem—with huge amounts of plastic ending up in landfills or incinerators.

The Ministry of Environment, in conjunction with stakeholders from the business and retail sectors, created a unified deposit system with an initial investment from the state. The Dansk Retursystem, a not-for-profit organisation, was created to have the monopoly over and handle the collection of beverage packaging in collaboration with supermarket chains. Following this system, the beverage producers deposit some money to the Dansk Retursystem, which, in turn, pays the supermarkets based on the packaging collected. Lastly, the supermarkets pay the producers back based on the packaging returned. Bottle prices include an extra cost for packaging. When consumers return the empty bottles to the supermarkets, they get the extra cost for packaging back.

After 20 years, key results include: 95% of all plastic bottles sold are now returned (the highest rate in Europe), and every time 100 bottles are recycled, 6 kilograms of raw materials are saved. The return rate for all disposable packaging (including cans and glass bottles) reached 93% in 2021.

More information can be found on the Dansk Retursystem website

4.5 The future of Ireland's agrifood sector

The Irish Government has made efforts to transition its agrifood sector towards greater sustainability, resilience and innovation through the creation of a strategy,[131] *Climate Action Plan 2021,*[132] *Ag Climatise—A Roadmap towards Climate Neutrality,*[133] *Whole of Government Circular Economy Strategy 2022–2023,*[134] *Waste Action Plan for a Circular Economy*[135] and a *National Food Waste Prevention Roadmap 2023–2025.*[136] The goals and actions in these strategies can be mapped to the three circular agrifood pillars and the circular economy strategies framework, to understand to which extent the strategies have embraced circular economy principles.

For example, the goal to improve water quality includes targets to reduce nutrient losses from agriculture to waters by 50% by 2030. To achieve this, actions mainly focus on **narrowing** material flows (for example, reducing nitrous oxide and ammonia emissions can be achieved by incorporating fertiliser additives and changing management practices)[137] and **regenerating** ecosystems (for example, there is a strong focus on the restoration of peatlands, which leads to water quality improvements). However, few other regenerative actions are mentioned, nor are actions anticipated to **cycle** flows (for example, nutrient recovery in local waste water plants)[138]—an example of a gap that Irish agrifood stakeholders can consider in the future.

A number of conclusions can be made from this analysis, outlined below.

Regenerative and, where appropriate, local food production

Actions around food production focus on reducing GHG emissions through technical interventions such as improving livestock feed (chemically), and modifying nitrogen fertilisers. At the same time, there are efforts to increase carbon sinks (for example, through afforestation practices, restoration of peatlands and marine protected areas) to compensate for the emissions produced from food production.

The strategies laid out in the documents do not explicitly promote regenerative agricultural practices, however, there are two main links to regenerative practices. The first is linked to organic farming: there are aims to dedicate 7.5% of total farmland to organic agriculture, up from current levels of less than 2%. Although this would be a major endeavour in the Irish context, this would also still leave Ireland trailing behind other European countries, as the EU average is already 9%.[139] The other link refers to cutting the use of nitrogen fertilisers through the '*inclusion of legumes in swards and the sowing of multispecies swards*'[140,141] —with no mention of crop-rotation, low/zero-till activities, or green manure.

Moreover, there is no mention of reducing livestock numbers—despite this being the biggest source of GHG emissions in the sector—or localising food chains. When it comes to nitrous oxide (deriving mainly from chemical fertilisers) and biogenic methane emissions (stemming from livestock raising), few actions are in place to achieve regeneration.

Low-impact and healthy diets

Government strategies to improve diets are focused on health rather than environmental concerns. There is no mention of promoting low-impact diets (those incorporating more vegetables, fruits and plant-based proteins, for example). To this end, there is no overt interest in awareness-raising activities targeted at improving public understanding of the environmental impacts of Irish diets and food production.

Designing waste out of food and food packaging

Food waste and loss will be tackled through a food waste prevention roadmap,[142] which aims to lay the path towards halving food waste by 2030. The roadmap sets out interim goals alongside a robust national monitoring and reporting system to track progress, based on preventing, and cycling unavoidable food waste for other purposes. Packaging waste lacks a focus on reducing the sheer consumption of resources and instead aims to increase recycling capacity. Moreover, little attention is given to using renewable, bio-based materials as well as slowing the flow of packaging through reuse initiatives.

Overall, the activities lined up in the various strategy documents demonstrate a **predominant focus on lowering the impact of activities** (the output) **without tackling the source of impact** (the root cause), especially concerning GHG emission reduction. There is a **moderate focus on cycling activities**, mostly centred on the recycling of packaging. A **moderate focus is given to regenerating** the system which could be strengthened by putting soil health at the heart of the decision making, as well as promoting more sustainable, bio-based packaging. Finally, **little focus is given to slowing activities**, which are less applicable to the agrifood sector compared to other sectors, but still play an important role in some areas to enhance the lifespan of natural resources in circulation, as well as processed food products and packaging.

Table 1 displays how the goals and actions laid out in the *Food Vision 2030* strategy,[143] *Climate Action Plan 2021*,[144] *Roadmap towards Climate Neutrality*,[145] *Waste Action Plan for a Circular Economy*[146] and the draft *National Food Waste Prevention Roadmap*[147] relate to the three circular agrifood pillars and how they impact each circular economy strategy (repeated below for ease of reading), allowing us to highlight where strengths and gaps exist in these policy documents.

Narrow flows—Use less	The amount of materials (including fossil fuels) used in the making of a product or in the delivery of a service are decreased.
Slow flows—Use longer	Resource use is optimised as the functional lifetime of food and packaging is extended.
Regenerate flows—Make clean	Fossil fuels, pollutants and toxic materials are replaced with regenerative sources, thereby increasing and maintaining value in natural ecosystems.
Cycle flows—Use again	The reuse of materials or products at end-of-life is optimised, facilitating a circular flow of resources.

Table 4.1: *depicts how Ireland's policies (see above) relate to the circular agrifood pillars and how they impact each circular economy strategy.*

HIGH	Strategies are in place that directly impact the circular economy strategy
MEDIUM	Strategies are in place that partially impact the circular economy strategy
LOW	Strategies in place have no or little impact on the circular economy strategy

	GOAL	NARROW	SLOW	CYCLE	
Regenerative and, where appropriate, local food production	Water quality: The Strategy commits to reducing nutrient losses from agriculture to water by 50% by 2030.	HIGH	N/A[98]	LOW	MEDIUM
	Biogenic methane: The Strategy commits to a reduction of at least 10% by 2030 (on 2018 level).[99]	HIGH	N/A	MEDIUM	LOW
	Nitrous oxide: Emissions associated with chemical fertiliser use to reduce by more than 50% by 2030.	HIGH	N/A	N/A	LOW
	Air quality: Ammonia emissions are to be reduced to 5% below 2005 levels by 2030.	MEDIUM	N/A	N/A	MEDIUM
	Biodiversity: It is envisaged that by 2030, 10% of farmed area will be prioritised for biodiversity, spread across all farms throughout the country.	MEDIUM	N/A	LOW	MEDIUM
	Forestry: Increase afforestation from existing levels to at least 8,000 hectares per year and double the sustainable production of biomass from forests to 2 million tonnes by 2035.	MEDIUM	N/A	MEDIUM	MEDIUM
	GOAL	NARROW	SLOW	CYCLE	REGENERATE
	Organic farming: At least 7.5% of utilisable agricultural area is targeted to be farmed organically by 2030.	MEDIUM	N/A	MEDIUM	MEDIUM
	Seafood: Achieve 30% of marine protected areas by 2030.	HIGH	MEDIUM	N/A	MEDIUM
	Origin Green programme: Achieve a high participation rate by both primary producers and the food industry in an enhanced Origin Green programme.	HIGH	LOW	HIGH	MEDIUM
Low-impact and healthy diets	Low-impact and healthy diets: Prioritise coherent food and health policies to deliver improved health outcomes Enhance consumer trust in our food system, providing evidence of a safe, ethical food supply	LOW	LOW	LOW	LOW
	Packaging: Ensure that all plastic packaging is reusable or recyclable by 2030. Increase capacity to recycle packaging waste by 70%, and plastic package waste by 55%. Provide for 90% collection of plastic drinks containers by 2029. Determine and introduce reduction targets and measures no later than 2022 to be achieved no later than 2026.	LOW	LOW	HIGH	LOW
Designing waste out of food and food packaging	Food waste: The Strategy aims to halve the level of food waste per person by 2030.	MEDIUM	MEDIUM	MEDIUM	N/A

98 Not all circular strategies are applicable to all goals, for example slow strategies are less applicable to improving water quality whereas they are much more applicable to reducing food packaging waste.

99 This target is subject to adjustment to align with upcoming national and international targets and in line with the development of scientific solutions.

4.6 Conclusion & recommendations for a circular agrifood system in Ireland

A global and systemic perspective on circularity.

As a high-income country, Ireland exhibits typical characteristics of other high impact countries—excessive material consumption and waste generation. [148] This material metabolism largely exceeds sustainable planetary boundaries. Accordingly, high-income countries are responsible for the social and environmental externalities that predominantly affect low-, lower-middle and upper-middle income countries. [149]

For this reason, governments must play a fundamental role—through policy and legislation—in leading the transition to a circular agrifood sector. Hence, the government must focus its policymaking on shifting the attitudes and perceptions of consumers (for example, through awareness-raising and educational campaigns about low-impact and healthy diets) and farmers (for example, supporting regenerative agricultural practices and shorter food chains with loans, financial subsidies, public procurement ratios, built infrastructure and rules for publicly-owned land).

Policymaking must take a systems perspective, supporting various actors along the value chain and encouraging collaboration between stakeholders (for example industrial symbiosis [150] and 'bundle of buyers' approach [151]). **Reducing packaging and making reusable, recyclable and bio-based packaging must be a priority for the government alongside dramatically cutting down on food waste.** High-income countries should set thematic reduction targets with specific and quantifiable measures to achieve them. This can then be translated into solid goals which can instil the ambition necessary to drive change: [152] Ireland must set ambitious goals and indicate concrete actions to attain them.

A circular perspective to identify gaps to move towards a more sustainable sector

The analysis in this report finds that the Government of Ireland has several areas that can be greatly improved to transition to a more circular agrifood sector. **The Irish strategies and actions around food production lack focus on regenerative agricultural practices and do not consider the sheer quantity of livestock as problematic in itself** (**regenerate** and **narrow**).

Accordingly, the goals of reducing nitrous oxide, biogenic methane, and CO_2 emissions (in turn to improve air and water quality) strongly rely on technological fixes (for example manipulating livestock diets and fertilisers) and increasing the number of carbon sinks. However, adopting natural fertilisers (for example, green manure and compost) and natural livestock feed (for example, through silvopasture and rotational grazing) have a regenerative impact on soil health and biodiversity. Naturally-produced fertilisers cut the emissions involved in the production and transport of the artificial inputs, since they are produced from renewable sources.

Government plans to tackle circularity in food processing, retailing and consumer diets could also be more ambitious. **The proposed actions focus more on recycling (cycle) of packaging materials rather than reducing packaging (narrow) or promoting bio-based (regenerate) and reusable (slow) packaging.** Lastly, greater efforts and attention should be drawn to shifting to low-impact and healthy diets (**narrow** and **regenerate**).

Ireland must embrace systems thinking

Ireland is a food exporting nation: around 90% of all food produced is exported to countries around the world.[153] The outward-looking sector has been built on a reputation of selling high-quality, sustainable produce. Despite some highly ambitious goals, several areas still lack attention, as identified in the previous section. It must be asked if having such a strong focus on exports gives room to transition to a more sustainable agrifood sector with soil health at its heart.

Trade-offs must be considered

A circular food system cannot be suddenly realised in our current, mostly-linear food system. Many obstacles stand in the way, which will require—as noted—intervention across all levels of governance, changes of practices by businesses and farmers as well as cultural shifts to overcome. This systemic transformation will spur certain trade-offs, where some outcomes will need to be favoured over others. For example, measures to reduce GHG emissions may negatively affect biodiversity: think of reforestation/afforestation practices that only use one species of tree rather than a variety of native trees. Additionally, the scale at which an intervention is conducted can highly influence the environmental outcome. Given the market-driven system prevalent globally, interlinkages between supply and demand can mean that if yield is sacrificed to reduce environmental impacts in one place, then the demand will be met by another place that may not have the same standards of environmental governance. Thus, practices such as intensification may be performed which could have an overall negative impact on the food system.[154] Potential trade-offs must be considered through a systemic lens when considering and implementing circular agricultural practices.

A reliance on technology alone isn't enough

Efforts to maintain the livestock population, whilst meeting a range of linked environmental goals, shows the limitations of new technology and improved management practices alone. These incremental improvements are likely insufficient to create the changes required to operate within planetary boundaries. A more holistic, systems-level approach must be taken, considering the Irish environment as one complex ecosystem where all actions are intertwined.

Ensuring a just transition

Given how deeply ingrained agriculture is in Irish society and culture, considerations must also go beyond environmental factors to ensure that a just transition can be achieved—leaving no farmers and businesses behind, whilst allowing the sector to thrive. The transition must carefully manage and address issues such as the gender pay gap, ageing workforce, and profitability of small farms, and ensure adequate education and training is available to equip the future workforce with the resources and skills needed to operate the sector more sustainably. The transition must also consider international impacts, particularly on trade partners in lower-income countries.[155] This report does not focus on the social aspect, but instead stresses here its importance and highlights the need for future research in this area.

4.7 References

1. Tilman, D., Clark, M., Williams, D. R., Kimmel, K., Polasky, S., & Packer, C. (2017). Future threats to biodiversity and pathways to their prevention. Nature, 546(7656), 73-81. doi:10.1038/nature22900
2. Campbell, B. M., Beare, D. J., Bennett, E. M., Hall-Spencer, J. M., Ingram, J. S., Jaramillo, F., . . . Shindell, D. (2017). Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and Society, 22(4). doi:10.5751/es-09595-220408
3. Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. (2021). Food Systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198-209. doi:10.1038/s43016-021-00225-9
4. The Food and Agriculture Organisation of the United Nations (FAO). (2020). Land use in agriculture by the numbers. Retrieved from: FAO website
5. Central Statistics Office (CSO). (2020). Census of Agriculture 2020 - Preliminary Results. Retrieved from: CSO website
6. Eurostat. (2022). Organic farming statistics. Retrieved from: Eurostat website
7. Wageningen University and Research (WUR). (n.d.). Effects of agricultural intensification on biodiversity and ecosystem processes on European farmland. Retrieved from: WUR website
8. Department of Agriculture, Food and the Marine. (2022). F*ood Vision 2030: A World Leader in Sustainable Food Systems.* Retrieved from: Irish Government website
9. Department of Agriculture, Food and the Marine. (2022). Forestry facts and news. Retrieved from: Irish Government website
10. Project Woodland. (2022). *Shared National Vision.* Retrieved from: Irish Government website
11. Ellen MacArthur Foundation (EMF). (n.d.). What is a circular economy? Retrieved from: EMF website
12. Bocken, N., de Pauw, I., Bakker, C. & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering 33*(5), 308-320. doi:10.1080/21681015.2016.1172124
13. Ellen MacArthur Foundation (EMF). (2019). *Cities and circular economy for food.* Retrieved from: EMF website
14. This report places more of a focus on low-impact diets rather than on healthy diets for conciseness. The EAT-Lancet Commission report can be referred to for a more comprehensive guide to the link between the environmental and health considerations.
15. Circle Economy & Zero Waste Scotland. (2020). *The future of work: baseline employment analysis and skills pathways for the circular economy in Scotland.* Retrieved from: Circle Economy website
16. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
17. Circle Economy. (2022). *The circularity gap report Scotland.* To be published. Amsterdam: Circle Economy.
18. SITRA news. (2022, May 16). Circular solutions can halt biodiversity loss – the food and agriculture sector can make the largest contribution. Retrieved from: SITRA website

19. Horrigan, L., Lawrence, R. S., Walker, P. (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives, 110*(5), 445–456. doi: 10.1289/ehp.02110445
20. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
21. Volterra Ecosystems S.L. (2020). Regenerative agriculture. Opportunities and challenges to catalyse profitable and resilient agricultural systems in the context of climate change. Volterra Bio website
22. Liaros, S. (2021). Circular Food Futures: what will they look like? *Circular Economy and Sustainability. 1,* 1193–1206. doi: 10.1007/s43615-021-00082-5
23. Stein, A. J., & Santini, F. (2022). The sustainability of "local" food: A review for policy-makers. Review of Agricultural, Food and Environmental Studies, 103(1), 77–89. doi:10.1007/s41130-021-00148-w
24. Giller, K. E., Hijbeek, R., Andersson, J. A. & Sumberg, J. (2021). Regenerative agriculture: An agronomic perspective (p. 19). *Outlook on Agriculture, 50*(1), 13–25. doi:10.1177/00307270211998063
25. Giller, K. E., Hijbeek, R., Andersson, J. A. & Sumberg, J. (2021). Regenerative agriculture: An agronomic perspective. *Outlook on Agriculture, 50(*1), 13–25. doi:10.1177/0030727021998063
26. FAO. (2015). Agroforestry. Retrieved from: FAO website
27. SYSTEMIQ. (2020). *Regenerating Europe's soils: making the economics work.* Retrieved from: SYSTEMIQ website
28. Circle Economy. (2016). *The circular dairy economy: Exploring the business case for a farmer led, 'net-positive' circular dairy sector.* Retrieved from: Circle Economy website
29. Bingham, J. & Warner, H. (2021). *Roots of the future: the businesses regenerating Africa's soils.* Accra: Footprints Africa. Retrieved from: Footprints Africa website
30. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
31. LaCanne, C. E., & Lundgren, J. G. (2018). Regenerative agriculture: merging farming and natural resource conservation profitably. *Peer Journal, 6,* e4428. doi:10.7717/peerj.4428
32. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
33. LaCanne E. C. & Lunggren G. J. (2018). Regenerative agriculture: merging farming and natural resource conservation profitability. *Peer Journal, 6.* doi:10.7717/peerj.4428
34. Kenny, D. C. & Castilla-Rho, J. (2022). What prevents the adoption of regenerative agriculture and what can we do about it? lessons and narratives from a participatory modeling exercise in Australia. Land, 11(9), 1383. doi: 10.3390/land11091383
35. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
36. Gilchrist, J. (2021). *The promise of regenerative agriculture.* Retrieved from: E2 website
37. Gish, S. (2022). *Drivers and barriers of the transition to regenerative agriculture within the EU's common agricultural policy reform: comparative analysis with the US Farm Bill.* Retrieved from: School for International Training Digital Collection website
38. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
39. FAO. (2014). *Sustainable local procurement.* Retrieved from: FAO website
40. Gilchrist, J. (2021). *The promise of regenerative agriculture.* Retrieved from: E2 website
41. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
42. Gish, S. (2022). *Drivers and barriers of the transition to regenerative agriculture within the EU's common agricultural policy reform: comparative analysis with the US Farm Bill.* Retrieved from: School for International Training Digital Collection website
43. Clapp, J. & Purugganan, J. (2020). Contextualizing corporate control in the agrifood and extractive sectors. *Globalizations.* doi: 10.1080/14747731.2020.1783814
44. Bloomberg. (2021, 14 September). Ireland takes on powerful farm lobby to meet climate goals. Retrieved from: Bloomberg website
45. Gilchrist, J. (2021). *The promise of regenerative agriculture.* Retrieved from: E2 website
46. ICLEI. (2021). *City practitioners handbook: circular food systems.* Retrieved from: ICLEI website
47. ICLEI. (2021). *City practitioners handbook: circular food systems.* Retrieved from: ICLEI website
48. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website

49. SYSTEMIQ. (2020). *Regenerating Europe's soils: making the economics work.* Retrieved from: SYSTEMIQ website
50. Anderson, C. R., Bruil, J., Chappell, M. J., Kiss, C. & Pimbert, M. P. (2019). From transition to domains of transformation: getting to sustainable and just food systems through agroecology. Sustainability, 11(19), Article 19. doi:10.3390/su11195272
51. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
52. Sharma, A., Bryant, L. & Lee, E. (2022). *Regenerative agriculture: farm policy for the 21st century, policy recommendations to advance regenerative agriculture.* Retrieved from: Natural Resources Defence Council website
53. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
54. Local Government Association. (2022, 23 June). Devon County Council and the Apricot Centre: future of farming – training the next generation of regenerative farmers. Retrieved from: Local Government Association website
55. ICLEI. (2021). *City practitioners handbook: circular food systems.* Retrieved from: ICLEI website
56. FAO. (2014). *Sustainable local procurement.* Retrieved from: FAO website
57. Gilchrist, J. (2021). *The promise of regenerative agriculture.* Retrieved from: E2 website
58. Ritchie, H. & Roser, M. (2021). Forests and deforestation. *Our World in Data.* Retrieved from: Our World in Data website
59. Poore, J. & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science 360(639),* 987-992. doi:10.1126/science.aaq0216
60. EAT. (2022). The EAT-Lancet commission on food, planet, heath: the planetary health diet. Retrieved from: EAT website
61. Stockholm Environment Institute. (2022). *A just transition in the meat sector: why, who and how?* Retrieved from: Stockholm Environment Institute website
62. World Resources Institute. (2022, March 7). 7 Opportunities to reduce emissions from beef production. Retrieved from: World Resources Institute website
63. U.S. Department of Agriculture (USDA). (n.d.). Silvopasture. Retrieved from: USDA website
64. World Business Council for Sustainable Development. (2020). *Food and agriculture roadmap: chapter on healthy and sustainable diets.* Retrieved from: WBCSD website
65. Ellen Macarthur Foundation. The big food design: making nature positive food the norm. Retrieved from: Ellen Macarthur Foundation website
66. Ellen Macarthur Foundation. The big food design: making nature positive food the norm. Retrieved from: Ellen Macarthur Foundation website
67. World Business Council for Sustainable Development. (2020). Food and agriculture roadmap: chapter on healthy and sustainable diets. Retrieved from: WBCSD website
68. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
69. Bacon, L., Wise, J., Attwood, S., Vennard, D. (2018). *The language of sustainable diets: a field study exploring the impact of renaming vegetarian dishes on U.K. café menus.* Retrieved from: WRI website
70. Steer-Stephenson, C. (2022, 23 August). Supermarket eco-labels to boost sustainability transparency. Retrieved from: Sustainability Mag website
71. Just Food. (2021, 27 June). Food giants sign up to new Foundation Earth eco-labelling scheme. Retrieved from: Just Food website
72. Soni, A. (2020). Why are consumers not reducing their meat consumption in Ireland? Establishing the reasoning for this. *Master's thesis, National College of Ireland,* 2020. Dublin: National College of Ireland.
73. Hartmann, C., Lazzarini, G., Funk, A., & Siegrist, M. (2021). Measuring consumers' knowledge of the environmental impact of foods. *Appetite,* 167, 105622. doi: 10.1016/j.appet.2021.105622
74. Circle Economy. (2021). *National policy instruments framework.* Retrieved from: Circle Economy website
75. Gilchrist, J. (2021). *The promise of regenerative agriculture.* Retrieved from: E2 website
76. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
77. Soldi, R., Cavallini, S. (2020). *The role of local and regional authorities in making food systems more sustainable.* Brussels: European Committee of the Regions. Retrieved from: European Committee of the Regions website

78. Soldi, R., Cavallini, S. (2020). *The role of local and regional authorities in making food systems more sustainable*. Brussels: European Committee of the Regions. Retrieved from: European Committee of the Regions website
79. Kenny, D. C., & Castilla-Rho, J. (2022). What prevents the adoption of regenerative agriculture and what can we do about it? lessons and narratives from a participatory modeling exercise in Australia. *Land, 11*(9), 1383. doi:10.3390/land11091383
80. Agriculture and Food Development Authority. (n.d.). Agriculture in Ireland. Retrieved from: Agriculture and Food Development Authority website
81. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website
82. Circle Economy. (2021). *National policy instruments framework*. Retrieved from: Circle Economy website
83. European Commission. (2018). *Circular catering services for the Pļaviņu Gymnasium*. Retrieved from: Circular Innovation Council website
84. World Resources Institute. (2013). *Reducing food loss and waste.* Retrieved from: World Resources Institute website
85. The Greenery. (2022). A cardboard box made from tomato stems. Retrieved from: The Greenery website
86. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website
87. PACE. (2021). *Circular economy action agenda: food*. Retrieved from: PACE website
88. Interreg Europe. (n.d.). *The CESME White Book*. Retrieved from: CESME website
89. World Resources Institute. (2013). *Reducing food loss and waste*. Retrieved from: World Resources Institute website
90. Feeding Liverpool. (2022, 14 June). Plenty to share: food abundance and equality declaration. Retrieved from: Feeding Liverpool website
91. World Resources Institute. (2013). *Reducing food loss and waste*. Retrieved from: World Resources Institute website
92. Feedback. (2018). *The food waste scorecard: an assessment of supermarket action to address food waste*. London: Feedback. Retrieved from: Feedback website
93. Albert Heijn. (2022). Mission report 2021: food waste. Retrieved from: Albert Heijn website
94. World Business Council for Sustainable Development. (2020). *Food and agriculture roadmap: chapter on healthy and sustainable diets*. Retrieved from: WBCSD website
95. The greenery. (n.d.). A cardboard box made from tomato stems. Retrieved from: the greenery website
96. ReCIRCLE. (n.d.). Mission. Retrieved from: ReCIRCLE website
97. ReCIRCLE. (n.d.). It goes around. Retrieved from: ReCIRCLE website
98. Circle Economy. (2021). *Climate change mitigation through the circular economy*. Retrieved from: Circle Economy website
99. PACE. (2021). *Circular economy action agenda: food*. Retrieved from: PACE website
100. Circle Economy. (2021). *Climate change mitigation through the circular economy*. Retrieved from: Circle Economy website
101. PACE. (2021). *Circular economy action agenda: food*. Retrieved from: PACE website
102. World Resources Institute. (2019). *Reducing food loss and waste: setting a global agenda*. Retrieved from: World Resources Institute website
103. Circle Economy. (2021). *Climate change mitigation through the circular economy*. Retrieved from: Circle Economy website
104. Canali, M., Amani, P., Aramyan, L., Gheoldus, M., Moates, G., Östergren, K., Silvennoinen, K., Waldron, K., & Vittuari, M. (2017). Food waste drivers in Europe, from identification to possible interventions. *Sustainability 9*(1). doi:10.3390/su9010037
105. World Resources Institute. (2019). *Reducing food loss and waste: setting a global agenda*. Retrieved from: World Resources Institute website
106. ICLEI. (2021). *City practitioners handbook: circular food systems*. Retrieved from: ICLEI website
107. GOV.UK. (2022, 14 May). Government delays restrictions on multibuy deals and advertising on TV and online. Retrieved from: GOV.UK website
108. Circle Economy. (2021). *Climate change mitigation through the circular economy*. Retrieved from: Circle Economy website
109. PACE. (2021). *Circular economy action agenda: food*. Retrieved from: PACE website
110. ICLEI. (2021). *City practitioners handbook: circular food systems*. Retrieved from: ICLEI website

111. Sharma, A., Bryant, L. & Lee, E. (2022*). Regenerative agriculture: farm policy for the 21st century, policy recommendations to advance regenerative agriculture*. Retrieved from: Natural Resources Defence Council website

112. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website

113. ICLEI. (2021). *City practitioners handbook: circular food systems*. Retrieved from: ICLEI website

114. PACE. (2021). *Circular economy action agenda: food.* Retrieved from: PACE website

115. World Resources Institute. (2022). *Making food waste socially unacceptable: what behavioural science tells us about shifting social norms to reduce household food waste.* Retrieved from: World Resources Institute Website

116. Circle Economy. (2021). *Climate change mitigation through the circular economy.* Retrieved from: Circle Economy website

117. World Resources Institute. (2022). *Making food waste socially unacceptable: what behavioural science tells us about shifting social norms to reduce household food waste.* Retrieved from: World Resources Institute Website

118. World Resources Institute. (2019). *Reducing food loss and waste: setting a global agenda.* Retrieved from: World Resources Institute website

119. World Resources Institute. (2022). *Making food waste socially unacceptable: what behavioural science tells us about shifting social norms to reduce household food waste.* Retrieved from: World Resources Institute Website

120. Almassy, D., Pulawska, G. (2021). *Drivers and barriers for the reduction of single-use plastics in the member countries of the Asia-Europe Meeting (ASEM).* Singapore: Asia-Europe Foundation (ASEF). Retrieved from: ASEF website

121. Távora de Mello Soares, C., Ek, M., Östmark, E., Gällstedt, M. & Karlsson, S. (2022). Recycling of multi-material multilayer plastic packaging: Current trends and future scenarios. *Resources, Conservation and Recycling,* 176. doi.org/10.1016/j.resconrec.2021.105905.

122. Christopher, S., Trott, P., van den Hende, E. & Hultink, E. (2020). Barriers to the adoption of waste-reducing eco-innovations in the packaged food sector: A study in the UK and the Netherlands. *Journal of Cleaner Production, 244*. doi:10.1016/j.jclepro.2019.118792

123. World Economic Forum. (2022). How national policies can accelerate the transition to a reuse economy. Retrieved from: World Economic Forum website

124. European Commission. (2019). *The Single Use Plastics Directive*. Retrieved from: EUR-Lex Access European Union Law

125. World Economic Forum. (2022, 18 January). How national policies can accelerate the transition to a reuse economy. Retrieved from: World Economic Forum website

126. ICLEI. (2021). *City practitioners handbook: circular food systems*. Retrieved from: ICLEI website

127. WRAP. (2022). Love food hate waste: the issue with food waste. Retrieved from: WRAP website

128. UNEP. (2021). *UNEP Food waste index report 2021.* Retrieved from: UNEP website

129. Yamakawa, H., Williams, I., Shaw, P., Watanabe, K. (2017). Food waste prevention: lessons from the Love Food, Hate Wate campaign in the UK. *16th International Waste Management and Landfill Symposium. S. Margherita di Pula: Cagliari, Italy. 02-06 Oct 2017* (Conference paper). Retrieved from: ResearchGate website

130. Dansk Retursystem. (2022). *The story of a deposit system for a circular economy.* Retrieved from: Retur System website

131. Department of Agriculture, Food and the Marine. (2022). *Food vision 2030: a world leader in sustainable food systems.* Retrieved from: Irish Government website

132. Department of the Taoiseach. (2021). *Climate action plan 2021: securing our future.* Retrieved from: Government of Ireland website

133. Department of Agriculture, Food and the Marine. (2021). *Ag Climatise - a roadmap towards climate neutrality*. Retrieved from: Government of Ireland website

134. Department of the Environment, Climate and Communications. (2022). *Whole of government circular economy strategy 2022 – 2023*. Retrieved from: Government of Ireland website

135. Department of Communications, Climate Action and Environment. (2021). *A waste action plan for*

136. *a circular economy: Ireland's national waste policy 2020-2025.* Retrieved from: Government of Ireland website

137. Department of the Environment, Climate and Communications. (2022). *National food waste prevention roadmap 2023-2025*. Retrieved from: Government of Ireland website

138. Millar, N., Doll, J. E., Robertson, G. P. (2014). *Management of nitrogen fertilizer to reduce nitrous oxide (n2o) emissions from field crops*. Retrieved from: Michigan State University College of Agriculture & Natural Resources website

139. Not all circular strategies are applicable to all goals, for example, slow strategies are less applicable to improving water quality whereas they are much more applicable to reducing food packaging waste.

140. Eurostat. (2022). Organic farming statistics. Retrieved from: Eurostat website

141. Department of the Taoiseach. (2021). *Climate action plan 2021: securing our future* (p. 174, Rep.). Retrieved from: Government of Ireland website

142. These practices help to reduce nitrogen through combining different grass and legume species, of which some are nitrogen-fixing, while others are deep rooting, which bring more minerals up from lower down in the soil.

143. Source: Germinal. (2020). Breaking down multi-species swards for Irish farmers. Retrieved from: Germinal website

144. Department of Communications, Climate Action and Environment. (2021). *A waste action plan for*

145. *a circular economy: Ireland's national waste policy 2020-2025.* Retrieved from: Government of Ireland website

146. Department of Agriculture, Food and the Marine. (2022). *Food Vision 2030: A World Leader in Sustainable Food Systems.* Retrieved from: Irish Government website

147. Department of the Taoiseach. (2021). *Climate action plan 2021: securing our future*. Retrieved from: Government of Ireland website

148. Department of Agriculture, Food and the Marine. (2021). Ag Climatise - A roadmap towards climate neutrality. Retrieved from: Government of Ireland website

149. Department of Communications, Climate Action and Environment. (2021). A Waste Action Plan for

150. a Circular Economy: Ireland's National Waste Policy 2020-2025. Retrieved from: Government of Ireland website

151. Department of Communications, Climate Action and Environment. (2022). Ireland's National Food Waste Prevention Roadmap: Draft for Public Consultation. Retrieved from: Government of Ireland website

152. Circle Economy. (2021). *The Circularity Gap Report 2021*. Retrieved from: Circularity Gap Report Initiative website

153. Circle Economy. (2022). *Thinking beyond borders to achieve social justice in a global circular economy*. Retrieved from: Circle Economy website

154. Interreg Europe. (n.d.). *The CESME White Book.* Retrieved from: CESME website

155. PACE. (2021). *Circular Economy Action Agenda: Food*. Retrieved from: PACE website

156. European Environment Agency. (2022). How is Europe fighting against climate change? Retrieved from: European Environment Agency

157. Board Bia. (2022). Irish Food and Drink Exports Enjoyed a Record Year as Value of Sales Up 4% to €13.5bn in 2021. Retrieved from: Board Bia website

158. Benton, T. G., Harwatt, H. (2022). *Sustainable agriculture and food systems: comparing contrasting and contested versions.* Retrieved from: Chatham House website

159. Circle Economy. (2022). Thinking beyond borders to achieve social justice in a global circular economy. Retrieved from: Circle Economy website

5. Meat and dairy processors: the Irish net zero supply chain

Authors:
Stewart Gee | Saskia Visser
Alexandra Fox | Willow Sommer
Anne de Valença

Credit: Shuttershock

Acknowledgements

EIT Climate KIC would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Stewart Gee, Saskia Visser

Reviewers

Denyse Julien (EIT Climate KIC)

How to cite this Chapter:

EIT Climate KIC and Metabolic (2023). Meat and Dairy processors' role in influencing supply chain Chapter 5 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Meat and dairy processors: the Irish net zero supply chain.

Ireland prides itself on its green, family farm image and its reputation as one of the most carbon efficient and sustainable meat and dairy producers in the world. This image is a powerful part of the Irish Food and Drink Brand and contributes significantly to Ireland's ability to export about 90% of its production.

Total food and drink exports have risen by 23.2% between 2015 and 2021, with most of the growth occurring in the dairy sector. Recently released figures for 2022 indicate a further increase of 22% over 2021 for all food and drink exports to €16.7 billion. Ruminant exports in 2021 were valued in aggregate at €7.9 billion, of which 64.4% were delivered by dairy products. Exports of beef and dairy rose by 9% and 5% by volume respectively, but the most significant contributor to the overall increase in value, was because of the increase in the market prices for the product (Fig. 5.1).

Figure 5.1: *Irish food and drink export in 2022*[100]

The continuous growth in exports comes with a price, agriculture is consistently Ireland's largest GHG emitting sector, contributing 37.5% of all emissions in 2022, and overall emissions have increased by 11.4% since 1990 (Chapter 1). GHG emissions from the agricultural sector mainly come from livestock enteric fermentation, agricultural soil management and manure management. Enteric fermentation

100 Source Bord Bia Export Performance and Prospects Report 2022-2023

from livestock is the most prominent GHG emitter in the agricultural sector, with dairy farms showing the highest emissions per hectare. The high emissions can be attributed to the greater production intensity on dairy farms - including higher stocking rates, more energy intensive diets and higher use of fertilizers.

Climate mitigation activities need to be implemented at the primary production level to ensure climate targets are met. Yet, the responsibility for a climate-neutral supply chain includes, not only the farmers, but all parties across the value chain. Organisations across the value chain are also making net-zero commitments, which includes Scope 1 & 2 emissions reduction in their operations and Scope 3 emissions reductions which require action across their entire supply chain. These organisations must ensure a just transition, that meets investor and consumer expectations, maintains their social licence to operate, mitigates reputational damage, increase competitiveness, and protects their bottom line.

Given the significant economic impact of the Irish dairy and meat sector, it is imperative that the role of organisations both upstream (input manufacturers) and downstream (large brands/manufacturers & retailers) of the primary producers to realise the overall ambition of a climate-neutral supply chain in 2050 is explored.

This chapter starts by describing the current state of sustainability in the Irish meat and dairy value chains, describes European developments in the meat and dairy sector and highlights sustainability leaders in the meat and dairy sector. Followed by an overview of circular and carbon neutral innovations in these value chains and the chapter concludes with recommendations for the Irish government.

5.1 Current state of sustainability in Irish meat and dairy chains

Origin Green is Ireland's food and drink sustainability programme. The programme is a key factor in Ireland's success as a dairy and beef exporter. It unites government, the private sector and the full supply chain from farmers to food producers and right through to the foodservice and retail sectors. The programme is the worlds' only national food and drink sustainability programme. It enables the industry to set and achieve measurable sustainability targets that respect the environment and serve local communities more effectively. Origin Green is a voluntary sustainability accreditation programme that currently reaches 55,000 farms (c. 40% of all farms). The programme has accredited over 300 food related businesses in Ireland which covers over 90% of exported products and 70% of domestic retailers. 58 of these businesses have achieved 'Gold Standard' Certification in 2022.

Depending on the size of the business, accreditation is dependent on selecting a number of sustainability actions from a menu of options. Gold standard members go above and beyond the basic requirements setting a higher level of ambition. Many of Ireland's leading meat and dairy processing companies have achieved this gold standard in 2022. The standards set in Origin Green are very much aligned with international standards and many of the companies in Origin Green are also members of the international Sustainable Agriculture Initiative Platform, which seeks to harmonise sustainability programmes across the globe.

However, Origin Green has come in for criticism. This criticism stems from the fact that while Origin Green communications indicate an overall improvement in the emissions intensity of meat and dairy production in Ireland of about 6% in the period between 2014 to 2019. Whereas Publica data shows that carbon intensity of production improved up to 2015, and since then showed no statistical improvement for dairy and beef.[101]

At the manufacturing level Origin Green's 2021 progress report notes that member companies have set 2,779 sustainability targets and have committed to 13,600 initiatives since 2012. Impact of all these measures varies and is often reported in improvements per unit output rather than absolute improvements. In the period 2012 -2022 water quality, biodiversity and emissions indicators at the national level have all continued to degrade.

It is for this reason that Ireland's Food Vision 2030 strategy has a goal that specifically identifies 'Strengthening Origin Green & Sustainable Supports to Reflect a Higher Level of Ambition'. The focus on emission intensity as the key sustainability metric demanded by international markets, has not succeeded in delivering on Ireland's National Inventory Targets under IPCC. This poses a real and significant risk to Ireland's green family farm brand as international markets become more attuned to the nuances of sustainability marketing.

Origin Green has a strong foundation in the Science Based Targets and many of its industry members have signed up to address not just their scope 1 and 2 emissions but also their scope 3 (on farm and other suppliers) emissions. This is a significant commitment considering the vast majority of their carbon footprint is on farm and that they have targets of 35% reduction in emissions from energy and 50% from transport by 2030, set out in the national Climate Action Bill.

Dairy

Ireland has a very strong cooperative movement within the dairy sector. Almost all of the main dairy processors are farmer owned. This has created very integrated value chains and contributed to huge growth in the dairy sector since the abolition of quotas in 2012. Dairy is by far the most profitable farming system in Ireland with average incomes from dairy farms in 2021 (a very good year) being over €94k. Dairy farmers account for about 11% of all farmers (c. 15,000) in Ireland, but for over 40% of agricultural emissions (not including calves from the dairy herd that go into beef systems).

The dairy industry is very well organised and is represented by Dairy Industry Ireland, though individual companies are often present in many decision-making bodies. Individual companies also have a strong influence through several farming organisations including the Irish Creamery and Milk Suppliers Association (ICMSA), the Irish Farmers Association (IFA) and Macra na Feirme (organisation of rural youth, historically focusing on young farmers).

101 Convery, F. (2022, September 21). Climate Performance by Irish Ruminant Farming (Dairy, Beef, Sheep) - Looking Back. UCD Earth Institute Climate Policy for Ruminant Agriculture in Ireland. https://www.ucd.ie/earth/newsevents/climate-policy-agriculture-ireland-blog/climatepolicyforruminantagricultureinirelandblog1/.

Meat

The meat sector in Ireland, from farm through to processing and export, is one of the most important indigenous industries in the national economy, supporting in excess of 120,000 individual farmers and generating total sales of more than €4.5bn, with 2020 exports of approximately €3bn. Suckler beef farmers, other beef farmers (dry-stock) and sheep farmers achieved incomes of €10,900, €16,400 and €20,400 respectively. Rurally located meat processing plants act as a key economic contributor by providing direct employment in several Irish towns with additional supplementary jobs generated in distribution, transport and services.

Over the past decades the Irish beef meat sector has grown from a frozen commodity business into the fifth largest net beef exporter globally. The sheep meat sector is also export oriented supplying to over 30 markets placing Ireland as the fourth largest net exporter in the world and second largest in the EU. Irish pigmeat exports have also grown exponentially with increasing presence in international export markets.

The meat sector is less well integrated as compared to the dairy sector with very few cooperatives, most farmers are very wary of the role of the processors and the retailers (even though a very small percentage of Irish beef is actually sold in Ireland). According to the Department of Agriculture, Food and the Marine (DAFM), there are 41 meat processing plants licenced across Ireland processing beef, pig meat, and sheep meat. While there are a number of smaller processors, the sector is dominated by ABP, Kepak Group, Dawn Meats and Liffey Group.

Producer Incentive Schemes

Most of the dairy cooperatives have established their own sustainability schemes, where they pay a price premium per litre of milk to farmers implementing a set number of sustainability actions from a menu of options. These programmes complement the Origin Green accreditation scheme for dairy farmers, which is called the Sustainable Dairy Assurance Scheme (SDAS).

Most of these schemes have started only in the past few years and so far there has been no observable positive impact on overall emissions, biodiversity, soil or water quality. Tir Lan (formerly Glanbia) currently offers 0.5c/litre extra to farmers who implement a selection of sustainability measures on farm. This equates to a premium of about €3,000 per annum for the average dairy farmer. Kerry's Evolve programme estimates an extra €2,000 per annum for suppliers signing up to its scheme. Carberry are offering 1c per litre in 2023 and estimate this will be worth an additional €5,000 per year to suppliers who sign up. These incentive schemes support the sustainable supply of dairy. However, given the very favourable price trends over the past few years, and the level of ambition within the menu of sustainability options, there are questions regarding the overall impact of these programmes.

The favourable price trends for milk and its huge competitive advantage over meat production are driving expansion on dairy farms that are offsetting any marginal gains made through on-farm measures. The prices are also attracting more farmers into dairy which is driving up overall emissions. Price incen-

tives for sustainability actions are very welcome but are unlikely to result in real large-scale impact as long as milk prices continue to rise and there are no disincentives for not implementing measures. During the stakeholders' workshops organised by Climate KIC Deep Demonstration Project in 2022 stakeholders stated that for real impact to be made a price differential of up to 10c per litre would be required.

Incentive schemes from processors are less widespread in the meat sector, but ABP, one of Ireland's largest meat processors, has recently introduced the Advantage Beef Programme which pays a €0.20/kg premium for animals from farms that meet their sustainability criteria. This initiative is in its early stages and has a large emphasis on breeding to reduce methane emissions and shorten the length of time it takes to 'finish' an animal. It requires farmers to be a member of an existing sustainability scheme and also to have a nutrient management plan for their farm. The price premium per head of cattle is up to €200.

Food Vision 2030

Food Vision 2030 aims to develop a sustainable food system in Ireland that incorporates all three pillars of sustainability – environmental, economic and social. Both the meat (beef and sheep) and dairy sectors have established stakeholder groups under the auspices of Food Vision 2030, with the aim to agree specific measures to reduce emissions to meet the targets set (25% reduction on 2018 levels) for the agriculture sector as part of Ireland's Climate Action Plan. Both groups identified a number of very similar measures, both direct and enabling measures, to help achieve these targets. Of particular interest in their recommendations are voluntary reduction and extensification schemes, though the details of any scheme still needs to be elaborated

Though Food Vision 2030 aims to address all three pillars of sustainability, the two sub groups established were mandated to focus on emissions reduction with no mandate to address water quality, biodiversity or the other two pillars of sustainability. Even though, some measures proposed by stakeholder groups under the auspices of Food Vision 2030 do address, at least to some extent, all three pillars of sustainability; they have very different weightings, many measures focus on emissions only. Without considering sustainability across all three pillars, initiatives are likely to have limited success.

5.2 European developments in the meat and dairy sector

This section introduces initiatives within the EU that are moving meat and dairy processors towards a transition to more sustainable food supply chains. This need has been increasingly recognised by both public and private sector organizations and led to several initiatives being put into place in the last decade. An important aspect of these initiatives are so-called pre-competitive collaborations, where private sector organizations come together to align on shared targets. This allows them to pool their resources to bring about more effective changes. One example of such initiatives are industry wide sustainability certification and labeling, which make it easier for consumers to choose sustainable products. The second part of this section then highlights initiatives taken by individual processing companies, who are often also part of these collaborative efforts. These initiatives often overlap or complement each other, creating complex dynamics.

The role of beef and dairy processors in the EU Green Deal

The EU Green Deal recognises the key role that the food industry plays in the EU and its environmental impacts. For this particular issue area, it has developed its "Farm to Fork Strategy" which aims to transition the whole food chain to a more sustainable system[102]. It focuses on three groups: (1) the primary producers, (2) the processors, wholesalers and retailers and (3) the consumers. The primary producers section is the most extensive and provides many concrete interventions to be taken, while the processors are provided with less specific recommendations. The guidelines refer to responsible business and marketing, circular business models, shortening supply chains, packaging and nutrient labeling. By the end of 2023, the European Commission is planning on providing a legislative proposal on a framework to outline the interventions needed for a transition within the food sector more clearly. This will be an important development for all EU member states and its businesses, since regulation will likely become more stringent, also for processors.

Some collaborative sustainability initiatives in meat and dairy

Sustainable Agriculture Initiative Platform (SAI)

The Sustainable Agriculture Initiative Platform (SAI) is a key initiative of pre-competitive collaboration comprising the entire food value chain. It has over 170 members worldwide and applies the principles of collaboration and knowledge sharing. It takes a nested approach to the different relevant sectors and includes both the European Roundtable for Beef Sustainability (ERBS) and the Dairy Working Group.

The ERBS comprises over 20 organizations along the whole beef supply chain. In addition, certain countries have their own ERBS platform which brings together actors within that country. The countries that currently have their own platform are France, Germany, Ireland, Italy, Poland and the UK, which

102 https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf

together make up a significant proportion of beef meat production in Europe. Each of these platforms run country-level initiatives which align with the ERBS goals. The ERBS has targets set across different areas, including environment, animal medicine, animal health and welfare, and farm management. The environmental target is formulated as an intensity reduction of 15% in GHG emissions by 2025[103]. Each member is required to assess and report on this target annually.

The Dairy Working Group is a group of processors and buyers of dairy who work together to make the dairy sector more sustainable. The key mechanism for this is the Sustainable Dairy Partnership (SPD) which outlines the relationship between dairy processors and buyers to streamline the sustainability assessment process. The idea is that rather than auditing each individual farm, the processors put in place certain management systems, which the buyers can then rely on for sustainable procurement[104]. Processing companies act as coordinators between the primary producers - whom they work closely with, and the market that they sell their products to. The processors provide a report which summarizes their progress and their prioritized indicators. These indicators are flexible and can accommodate existing benchmarks from either legal requirement, industry standards or company-internal targets. It builds on the Dairy Sustainability Framework (DSF) which provides the overarching global criteria that the processors report on[105]. These criteria are high-level and allow for regionally specific initiatives to address required improvements. Around 30% of global milk production reports on these criteria set out by the DSF.

Ireland's Bord Bia (Food Board) has developed the Sustainable Beef & Lamb Assurance Scheme (SBLAS) using the ERBS platform, and works with producers, allied industry, processors, retail and civil society. In 2019 it reached 34.000 farms and is currently working towards improved carbon footprinting strategies[106]. Bord Bia is also a member of the Dairy Working Group, which aligns with its "Origin Green" program that assesses farms against its sustainability criteria[107].

Private actors that are members of SAI and based in Ireland include Dawn Meats, the Kepak Group, Lakeland Dairies, and the ABP Food Group[108]. Having both private and public sector actors involved in the SAI platform indicates that there is alignment between these actors on sustainability targets, which makes compliance for primary producers easier.

103 https://saiplatform.org/faq/#ERBS
104 https://saiplatform.org/wp-content/uploads/2021/01/sdp-executive-summary_2021.pdf
105 https://dairysustainabilityframework.org/dsf-membership/global-criteria/
106 https://saiplatform.org/resource-centre/erbs/?document-id=10583&document-archive=erbs&document-action=Download&document-source=erbs-platforms-profile-ireland-bord-bia_2020.pdf
107 https://www.origingreen.ie/what-is-origin-green/how-does-origin-green-work/
108 https://saiplatform.org/members/sector/processor/

Duurzame Zuivelketen (DZK)

A national-scale example of dairy sustainability initiatives is the Duurzame Zuivelketen (sustainable dairy supply chain) partnership in the Netherlands. Its members are both dairy processors and primary producers, who work together towards more sustainable dairy supply chains. One example of how the initiative has successfully changed farming practices is the grazing program (Convenant Weidegang), which aims to increase the number of animals that graze outside on meadows, rather than being fed on animal feed[109]. Meadow grazing is a more natural way to feed cows, which improves animal welfare, and reduces the producer's dependence on feed, which can be expensive. Grasslands can contribute to carbon sequestration and local biodiversity, therefore improving a farm's environmental performance. Farmers are incentivized to join the program through payments, which are provided by the processors. In addition to this monetary incentive, farmers are also offered support from a "grazing coach" who eases the transition for the first two seasons. An independent audit is conducted on these farms to ensure that the minimum grazing requirements are met. The milk that these cows give is certified as "meadow milk" which allows consumers to make an informed decision about what kind of dairy production they would like to support. This initiative has been successful in increasing the number of farmers allowing their cows to graze, 84% of Dutch farmers now allow for at least partial grazing, which is higher than ever measured[110].

ClieNFarms

An example of knowledge generation and sharing facilitated by the public sector, the ClieNFarms project is an EU-funded project that aims to move the EU food chain towards meeting its targets laid out in the Farm to Fork Strategy. It is a space that allows actors to develop and upscale innovative, systemic solutions to transform the agricultural system to be climate neutral and resilient. Its members consist of a wide range of actors, such as farmers, research centers and processors[111]. Key processors included in this project are Danone, Friesland Campina, Nestle CH, and Nestle-UK, who are all big players in the dairy sector. The project funds Demonstration Farms, where new agricultural methods can be trialed, and - if successful- upscaled to other farms. Since this initiative comprises actors across the whole value chain, it enables an integrative, systemic approach. This means that the farm-level changes are not trialed in isolation but immediately linked to processors and the wider market, which ensures that these new methods are also economically viable.

Teagasc is leading Ireland's work with ClieNFarms, with both a dairy and a beef project ongoing. Two demonstration farms have been established, where sustainable methods are being tested. Both farms are comparing different types of pasture grazing (e.g. grass-only, multispecies swards, multispecies

109 https://www.duurzamezuivelketen.nl/themas/behoud-van-weidegang/
110 https://www.duurzamezuivelketen.nl/nieuwsberichten/record-aantal-boeren-laat-de-koe-buiten-lopen/
111 https://clienfarms.eu/project/

swards within agroforestry) to better understand the impacts of each method on nature[112] [113]. Data on indicators such as soil health and animal health is collected at these farms, which will enable concise measurement of outcomes and the application of these learnings to the specific Irish context.

Processor led initiatives for sustainable beef and dairy

This section profiles the highlights from corporate or private led initiatives for improving sustainability of beef and dairy production and processing. These initiatives are often developed in order to implement a processor's commitments to one of the pre-competitive initiatives listed above.

Biodiversity Monitor for Dairy Farming (Netherlands)

The Biodiversity Monitor for Dairy Farming[114] is a tool for measuring farm-level biodiversity impacts on dairy farms in the Netherlands. The tool was developed by FrieslandCampina, Rabobank and WWF-NL, in collaboration with scientists, stakeholders and farmers.

The Biodiversity Monitor includes seven outcome-based Key Performance Indicators (KPI):

1. Permanent grassland (% of total acreage)
2. Protein produced on own farm / in region <20 km (% of total protein feed)
3. Nitrogen soil surplus (kg N/ha)
4. Ammonia emissions (kg NH_3/ha)
5. Greenhouse gas emissions (kg CO_2-eq/ha and kg CO_2-eq/kg milk)
6. Herb-rich grassland (% of total acreage)
7. Nature & Landscape elements (% of total acreage)

The set of KPIs is linked to science- or policy-based thresholds and targets, which indicate the minimum performance required to stop further loss of nature (threshold) and the preferred performance for the recovery of nature (target).

The quantified biodiversity outcomes per farm can be used to financially reward dairy farms through supply chain partners and other stakeholders. FrieslandCampina uses the tool in their farm sustainability and incentive program Foqus Planet and also in their sustainability certification 'On the Way to Planet Proof'. Rabobank uses the tool in their Planet Impact Loans, which provides interest rate

112 https://clienfarms.eu/i3s/i11/

113 https://clienfarms.eu/i3s/i10/

114 Van Laarhoven et al. (2018) Biodiversity Monitor for the Dairy Farming Sector. A new tool for standardized quantification of biodiversity-enhancing performance in the dairy sector. See website: www.biodiversiteitsmonitor.nl

discounts to farms with positive biodiversity outcomes. The tool is available for other value chain stakeholders, such as governments, water authorities, and land owners, to use in incentive programs so dairy farms receive stacked financial rewards for a standard set of outcome indicators.

FrieslandCampina

FrieslandCampina[115] is a large-scale multinational dairy cooperative of farms in the Netherlands, Belgium and Germany. It's one of the largest cooperatives globally, processing dairy into about 40 brands including Friesche Vlag, Chocomel, Fristi, Optimel, Mona and Valess, Vifit, and Milner. The quality- and sustainability-programme Foqus Planet[116] is in place to ensure hygiene, quality, food safety, and animal welfare and stimulate better sustainability performance on dairy farms. Sustainable development is stimulated with financial incentives linked to performance on the topics climate, biodiversity, animal health and welfare, and outdoor grazing. The outcome indicators for climate and biodiversity are based on the Biodiversity Monitor for Dairy Farming (all indicators except for Herb-rich grassland). The outdoor grazing indicator is according to the Covenant Weidegang[117], initiated by Duurzam Zuivelketen, DZK (sustainable dairy supply chain initiative). The financial incentives for Foqus Planet performance are gradually scaled based on performance level. The incentives are partially covered by a redistribution of milk prices across cooperative members based on sustainability performance (rather than equal milk prices for cooperative members), and partially from company profits. Besides Foqus Planet, which is a mandatory program for all farms, the certification scheme On the Way to Planet Proof[118] rewards the 10% best performing farms with premium prices. Although only 1% of animal feed is from imported soy, Friesland Campina dairy farms have purchased 100% RTRS certified soy since 2015 to prevent deforestation risks.

Danone (Europe and North America)

Danone has various regenerative agriculture related programs to engage with its dairy suppliers across the United States, Europe and Russia. The company uses regenerative agriculture as an overarching mission to address their greenhouse gas, nature and social goals. The three main goals are to protect soils, empower farmers and farm workers and promote animal welfare. The tools they employ to achieve this are: farm assessment and knowledge building, cross-supply chain pilots, financial support programs and engagement at agricultural policy and implementation level.

115 https://www.frieslandcampina.com/nl/
116 https://www.frieslandcampina.com/nl/eigendom-van-boeren/foqus-planet/
117 https://www.duurzamezuivelketen.nl/onderwerpen/convenant-weidegang/
118 https://www.planetproof.eu/producten/melk/

Those triple goals are reflected in the Danone regenerative Ag scorecard[119], used to assess producers on a mixture of practices and outcomes for improved sustainability[120]. In addition to consulting scientific standards to develop the scorecard, Danone participated in a multi-stakeholder supply chain initiative called Farming for Generations which ran for 3 years from 2019. This program set up pilots across Germany, Spain and France and produced multiple knowledge tools which are now openly available and continuously used in implementation of their regenerative agriculture program[121]. The company uses target setting to spur corporate alignment across its parts. For example, Danone France has pledged to source 100% of its ingredients from regenerative production by 2025, and in 2023, Danone increased its ambitions around methane emissions, setting new targets for 2030[122]. To achieve these goals the company plans to work together with the European Commission and the United States Department of Agriculture, aiming to achieve results at scale.

Danone North America in particular has been focusing on dairy production, with around 90% of its sourcing acreage in the US being dairy farms. The Cool Farm Tool is used to calculate greenhouse gas, biodiversity and water impacts and is available online. They have been exploring the financial cost of transitioning to regenerative agriculture for farmers, one example of this is the $15 million Farmer Investment Fund that allows farmers who institute regenerative practices to access low or no-cost loans, to support them through the transition.

Some key self-reported highlights coming out of the five-year assessment of the program include:

- Regenerative management practices on dairy farms reduced 51,200 t CO_2-eq, which is equivalent to the average annual energy use of over 5,000 American homes and sequestered more than 14,227 tons of carbon.
- 70% of all dairy buildings in the program have been upgraded to LED lighting.
- Farmers placed cover crops on 69% of the program's acreage (national average for cover cropping is only 5%). Plus, 370,963 tons of natural manure fertilizer and 516 million gallons of natural manure effluent were applied – that reduced the need for synthetic fertilizers and avoided $7.3 million in costs.
- The farms in the program grew more than 30 species of cover and cash crops, promoting biodiversity.
- Farmers are able to identify areas of need and access funding and resources.[123]

119 https://www.danone.com/content/dam/danone-corp/danone-com/about-us-impact/policies-and-commitments/en/2021/Danone-regenerative-agriculture-2021-scorecard.pdf

120 https://www.danone.com/content/dam/danone-corp/danone-com/about-us-impact/policies-and-commitments/en/2021/Danone-regenerative-agriculture-2021-scorecard.pdf

121 https://www.danone.com/impact/planet/regenerative-agriculture.html

122 https://www.foodingredientsfirst.com/news/step-change-for-sustainable-dairy-danone-pledges-to-cut-methane-emissions-by-30.html

123 https://www.dairyprocessing.com/articles/1275-danone-north-america-sourcing-most-of-its-milk-from-regenerative-ag-farms

Together with a US-based consultancy firm, Danone North America has developed a tool which aims to help farmers calculate the risks and benefits of various components of the regenerative transition. The tool, R3, enables farmers to improve decision making and prioritization by using a model to forecast returns on investment in order to help them understand the potential financial impacts regenerative agriculture can have on their farm.[124]

Despite those well developed plans, primary producers require targeted support in their interactions with food processors, as they can be highly vulnerable to fluctuations in the market. This is highlighted by an example, where Danone North America, despite the comprehensive program for supporting dairy farmers in transition to regenerative agriculture, terminated 89 contracts with suppliers in the North-eastern region of the US, in favour of more economically convenient suppliers in the mid- and north-west region. Regardless of any progress on sustainability made, those northeastern farmers were dropped on the basis of economic supply chain considerations, which ultimately still take precedence[125].

Arla

Arla, a dairy farmer cooperative headquartered in Denmark, is asking their farmers to engage with a self-reporting online data tool. The Climate Check tool offers a score based on several KPIs related to climate, biodiversity and water. Arla expects to distribute €270m in its first full year. The cooperative is starting with 2.4c per litre, with aims to increase to 3 cents over time. For a farm that delivers 1.2M litres of milk 2.4c per litre would already bring in an additional €26.000. Although the program is ambitious, the scoring system favours climate related efficiency actions heavily, over those that protect biodiversity and water for example. This is done through the weighting system that Arla applies to the points received by farmers for their activities.

The "big 5" levers which receive the most points are:

- Feed efficiency
- Fertilizer use
- Land use
- Protein efficiency
- Herd robustness (animal health)

124 https://www.prnewswire.com/news-releases/danone-north-americas-soil-health-initiative-exceeds-2022-goal-further-advancing-a-leading-comprehensive-program-in-dairy-industry-301468961.html

125 https://civileats.com/2021/09/08/is-the-future-of-big-dairy-regenerative/

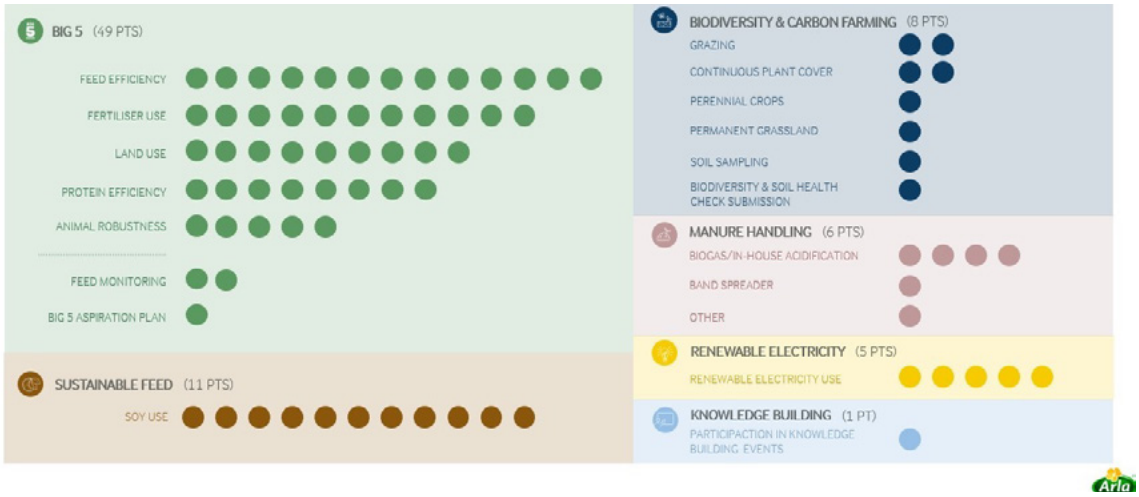


Figure 5.2; *The Arla Climate Check tool score based on several KPIs*

Arla began paying farmers according to their scores in 2023, and before the start, already 95% of farmers had registered with the online tool[126]. This program forms the bulk of the Sustainable Dairy Initiative which is part of Arla's larger sustainability strategy, which includes minimizing food waste, sustainable packaging, supporting communities, among others.[127]

General Mills

General Mills is a major agrifood company based in the US. Their regenerative dairy program is notable for its emphasis on training and learning with farmers. They have invested in a one-on-one "farmer classroom" where technical consultants work together with 3 major dairy farms (together providing 16% of total dairy sourcing), to learn and exchange on the principles and practices of regenerative agriculture over a minimum of three years. The plan for scaling is to partner with NGOs, conservation groups and public extension in order to multiply the spread of regenerative skills.[128] In collaboration with farmers, scientists and other practitioners, they have also developed a Regenerative Agriculture Self Assessment tool, which they continue to improve based on piloting and feedback, to make it more user friendly.[129]

General Mills is also part of an Ecosystem Services Market Consortium (currently only based in the US), which is looking into large scale implementation of payments for ecosystem services as a way to support farmers in the regenerative transition. They also have specific funds and scholarships available for young farmers interested in regenerative agriculture.[130]

126 https://www.dairyreporter.com/Article/2022/10/11/Arla-s-Sustainability-Incentive-explained-How-dairy-farmers-can-earn-extra-eurocents-for-their-milk
127 https://www.arla.com/sustainability/protecting-nature/
128 https://civileats.com/2021/09/08/is-the-future-of-big-dairy-regenerative/
129 https://www.generalmills.com/news/stories/empowering-farmers-to-self-assess-agricultural-practices
130 https://www.generalmills.com/news/stories/empowering-farmers-to-self-assess-agricultural-practices

Savencia

Savencia, a major French based dairy sourcing company, has a similar program to the above dairy processors. The company offers its producers a "Sustainable Milk Production" diagnosis, based on several indicators: farm profitability, sustainable management of water resources, carbon footprint, animal welfare, food self-sufficiency for the herd, biodiversity, soil fertility, producer's quality of life, outdoor access and herd health. Key to this program is the offer after assessment: farmers can select an area that they would like additional training in.

Some of the Indicators used to measure biodiversity include:

- Share of permanent pastures on farm
- Areas of ecological interest (hedges, trees, bodies of water etc)
- Diversity of animal and plant species on-farm[131]

Cargill (North America)

Cargill's sustainable beef program, focused on sourcing from the US and Canada, focuses on improving cattle raising standards with an emphasis on partnerships to achieve larger scale goals across the landscape.[132]

Their four-pillar program has a focus on:

- Grazing management
- Feed production
- Innovation
- Food waste reduction

Cattle production in North America is 30% less emissions intensive than the global average, due to the high reliance on grasslands. Cargill's program focuses therefore on implementing regenerative grazing management in order to improve soil health and biodiversity outcomes, while maximizing potential for carbon sequestration. Their overall goal is to cut beef supply chain emissions by 30% in North America by 2030. The approach seems to be based largely in partnerships between industry (buyers), often independent farmers (ranchers), and local conservation organizations and NGOs, facilitating pilots and upscaling of these more regenerative cattle raising practices.[133]

131 https://www.savencia-fromagedairy.com/wp-content/uploads/2022/06/NFPS_SAVENCIA-FD-2021_090622.pdf
132 https://beefup.wpengine.com/partnerships-in-action/
133 https://www.cargill.com/sustainability/sustainable-beef

Van Loon Group

A smaller, privately-held company, Van Loon Group is based in the Netherlands. Much of their sustainability program has focused on their processing facilities, and less on the producers they source from. They have been involved in supply chain initiatives such as Beter Leven, the Dutch animal welfare certification, and have even begun some more holistic supply chain initiatives more recently.[134] Van Loon Group's program for animal welfare, 'Varken op z'n Best' (Pork at its Best) aims to reduce the carbon footprint of a kilo of pork by 30 % by modifications to the feed and manure processing. For these programs to work and to transfer value to the farmer, smaller companies such as Van Loon rely heavily upon the marketing of higher quality/sustainable meat products in order to receive a higher price from consumers which can be passed on to producers for a premium price. In their CSR plan they state continuity of purchase guarantees as a key lever in their sustainability efforts with producers[135]. Interestingly, Van Loon is also acquiring brands focusing on meat substitutes as part of its future looking strategy, while continuing to improve its meat sourcing and processing sustainability.

New Zealand; Beef

New Zealand's largest red meat processor **Silver Fern Farms**[136] Net Carbon Zero by Nature Angus beef has been approved by the US Department of Agriculture and certified by NZ's agricultural science institution Ag Research and the country's environmental verification body, Toitū Envirocare. The key to Silver Fern's zero carbon methodology is 'insetting' – determining how much of the carbon produced is being absorbed by the local environment through on-farm vegetation including regenerating native bush, woodlot forests, shelter belts, summer shade and winter animal shelter, and erosion and riparian planting. This is complemented with improvements in genetics and animal performance. It is a world-leading programme that incentivizes farmers to invest in and maintain on-farm carbon sequestration including native and riparian planting. In order to produce net zero carbon meat Silver Fern Farms has been proactively working with a group of 17 farmer suppliers from across New Zealand, to better understand their own carbon footprint and the opportunities to optimise carbon stored on their farms. The next step was to map and measure the sequestration potential from the vegetation present on NZ farms. Satellite technology, aided by increasingly sophisticated AI software, has been used to measure on-farm vegetation to within half a metre, enabling a calculation of each

134 https://www.vanloongroup.com/en/value-chain-concepts

135 https://www.vanloongroup.com/uploads/files/14905%20Van%20Loon%20Group%20MVO%20jaarverslag%202021_EN_WEB.pdf

136 https://www.beefcentral.com/trade/carbon-neutral-beef-brands-continue-to-emerge-but-premiums-remain-elusive/

individual farm's ability to sequester carbon. Building on the information gathered from the pilot, Silver Fern Farms has launched the first range of Toitū Net Carbon Zero Certified Beef in the United States in early 2022. By adopting this approach farmers rely on purchasing carbon credits from outside source.

Uruguay; Beef

Similar to Ireland, Uruguay's agriculture sector is a key pillar of the economy, with cattle outnumbering people in the country by approximately four to one and the sector contributing more than 7% of gross domestic product. However, the agriculture sector is also responsible for producing an estimated 75% of the country's greenhouse gas emissions, with Uruguay's farmed livestock industry one of the biggest polluters.

A large part of this pollution can be attributed to methane and Uruguay was one of 106 countries to endorse the Global Methane Pledge at COP26, designed to decrease global emissions by 30 percent by 2030.

Carbon neutral meat is certified in Uruguay via a comprehensive "Cradle to Gate"[137] study of the production process carried out by LSQA (a national certification body), which monitors carbon emissions related to rearing livestock from the moment they are born, through the fattening up process, and up to the animals' arrival at the slaughterhouse.. These include standards from the International Organization for Standardization and rules on product categorization, and guidelines on greenhouse gases set forth by the Intergovernmental Panel on Climate Change. It also entails a "fingerprint inventory" that cattle farmers must self-produce to demonstrate their emissions, as well as efforts taken to mitigate them, all of which is verified by LSQA. According to LSQA, the status of carbon neutral meat is merit to using natural pastures, as well as through engagement in native forest conservation Certified Carbon Neutral beef was exported to Switzerland for the first time at the end of 2021.

137 https://dialogochino.net/en/agriculture/58402-farms-in-uruguay-driving-efforts-towards-carbon-neutral-beef/

The Netherlands; Eggs and Chicken

Kipster[138] is a forward-thinking award-winning Dutch egg farmer. In 2017, they introduced the world's first carbon-neutral egg to the Netherlands. Now, the eggs from the first American Kipster farm are available in the USA. Kipster processes waste, produces eggs and chicken meat with respect for life and nature in farms that are designed to assure it addresses the needs and instinct of the hen. Kipster 'saves' roosters; roosters are not killed (as usual) as soon as they hatch, but grown for their meat. By using upcycled feed, Kipster aims to avoid using land to grow crops for their chickens. The feed is circular, specially developed from leftovers from, for example, large bakeries. In this way they contribute to a better environment and prevent waste. No fields are needed to grow chicken feed. The Business model is smart; by making direct contracts with supermarkets and typical Dutch organisations that benefit from the sustainable branding like Efteling, Schiphol and KLM. As the reseller costs are avoided, margins on products are higher. All Kipster farms have a ventilation system, this removes dust, odor, ammonia, and other undesirable particles. Before the air leaves the barn, its heat is recovered by a heat pump which preheats incoming fresh air. Combined with the innovative ventilation system in the barn this lowers emissions significantly and creates a better in-house climate for both farmer and bird. Carbon emissions that can not be removed from the barn, are compensated by buying carnon credits. There is a 24/7 livestream[139] of the Kipster farm. Anyone can watch the hens online.

5.3 Innovations in the beef and dairy chains

Sustainability is a catalyst for change and innovation in both the meat and dairy industry. Political requirements and nutrition-conscious consumers are driving producers and manufacturers to act, and additional pressure is being generated by the global debate on climate protection and resource conservation. The food processing industry is responding to this with technological innovations, but also with fundamental corporate commitments to realise sustainable solutions. Obviously packaging is an important aspect of the entire food chain, circular approaches to packaging are already discussed in

138 KIPSTER
139 https://www.kipster.farm/#webcam

chapters 4 and 7 of this report, and will not be discussed here. Here we focus on innovations in machinery, improving the use of sideflows by animal rendering and by exploring the role of meat and dairy processors in the alternative proteins markets.

Reducing machinery emission; resource and energy management

The food processing industry is a high energy sector; heating and cooling food requires a lot of energy. Cold is needed to chill ensuring food safety; heat is needed for cooking, steaming, simmering, sterilization and cleaning. In addition, there is water consumption for cleaning and disinfecting manufacturing facilities. And of course there is the issue of heating the water, which consumes energy again. Innovation pathways for energy include both increasing energy efficiency and switching to renewables.

Energy-efficient refrigeration and heat pump solutions can improve energy efficiency in heating and cooling by up to 70 percent[140]. By applying smart design principles waste heat, can be reused and diverted to other processes such as water and brine heating, drying, cooking, blanching, pickling, pasteurizing, sterilizing, dehydrating and cleaning. To ensure a sustainable cold chain, compressor-based process cooling systems, among others, can be used to provide thermally optimal production environments - not only for the food itself, but also for storage and distribution areas. Ultimately, the design of the overall processing system, the smart connections that can be made within the processing chain, or in case useful also connections outside the production chain; think of providing heat to the grid to warm houses, requires a holistic analysis and design-approach. External advisors are generally best suited to provide an overall advice including options that may be beyond the influence of the processor.

Within the design of the machinery, an additional step towards sustainability can be made. Welded and rounded edges and recessed flush covers offer less contact-surface for dirt and germs; requiring less water and energy for cleaning. Regarding food safety, the motto for water consumption should be: "As much as necessary, as little as possible". To reduce water consumption to a minimum, various options are to be considered, that involved either in-company investment in recycling wastewater or agreements with municipal wastewater treatment plants. For food processing most processes require temperatures below 100 or 120 , hence renewable options like solar thermal energy, heat pumps, biogas or biomass are suitable. With cogeneration, electricity and heat can be efficiently provided from biogas or biomass from residual materials[141]

140 SEnS-GEA's Sustainable Engineering Solutions

141 Renewable Energy in the Food Processing Industry | Energy Central

The CleanSmoke smoking process is one of the innovations that can significantly save both energy and water compared to conventional smoking. Because of its special environmental compatibility, this modern process has already been awarded the title of "Best Available Technique" by the European Union.

CleanSmoke is a stable smoke freshly produced with compressed air from primary smoke condensate – free of harmful substances such as tar and ash and the contamination with polycyclic aromatic hydrocarbons (PAH) is largely eliminated. According to a study by the German Institute of Food Technologies (DIL), CleanSmoke technology, based on the German market for smoked products, can save around 50 percent energy and, at the current energy mix, around 30 percent greenhouse gas emissions.

https://cleansmoke.eu/en/2022/07/06/cleansmoke-approved-for-organic-products/

Efficient use of side flows

Though 50% of an animal is considered inedible by meat-eaters, that doesn't mean these by-products are unusable. However, by using animal rendering in their facilities, food production companies can reuse these unpalatable animal parts and recycle them into valuable products. Animal rendering is the process of reclaiming unwanted meat, scraps and other waste products from grocery stores and other food and agriculture industries; which are then used to create new products, ranging from personal care products to fertilizers to rubber.

Through this method, businesses can contribute to sustainability by helping to recycle water, reducing greenhouse gas emissions and minimizing waste. Some examples;

- **Feathers:** Rendering services take unwanted feathers as an animal by-product and use them in animal feed and fertilisers; reducing the need for fossil based fertilisers
- **Organ meat:** typically the meat from animal organs are not eaten in Western Europe, rendering grinds it up and makes it suitable for various food sources; reducing food waste, and the need to produce more proteins for food..
- **Fats:** Animal products typically contain high quantities of fat. Rendering implements numerous manufacturing processes for fat by-products, including deriving tallow for the cosmetics, plastics and paints industry and converting grease into biofuel or lubricant for food production equipment. Reducing the demand for fossil based resources.
- **Blood:** Through the rendering process, blood is usually dried, separated and turned into feed meal and fertilizers with added nutrition; reducing the need to produces additional feed

Rendering is an ongoing development that continuously creates new products from sideflows that would otherwise go to waste; it reduces the need for new raw materials, and can have a positicve impact on environment. New markets may emerge and for which new conditions and government regulations will be needed. In the future, it's expected that animal rendering will go through even more advancements that positively contribute to a more sustainable future as it discovers more efficient solutions and economical equipment. Already now people use rendered animal products every day in soaps, paints, varnishes, lubricants, caulking compounds, candles, cleaners, paints, polishes, rubber products, plastics, fertilizers, and even explosives. Renderers use materials such as fats, proteins, and oils to create all these products consumers need in everyday life. Many people just do not realize that rendered goods can be valuable for their daily life. Rendering has the potential to further educate consumers on the sustainable benefits of upcycling rendered materials into new products.

Plant-based proteins as an opportunity for the beef and dairy sector

The rise of meat and dairy alternatives has steadily taken over much of the market, with a huge range of plant-based replacements for basic meat products offered through-out the world. This trend is continuing to grow, and many new start-ups are offering new plant-based products all over the world. Plant-based R&D has refocused from mimicking meat, fish and dairy to optimizing and diversifying options. The largest international Food technology fair, IFFA 2022, had recognised that "more people are either consistently vegetarian or vegan or have become flexitarian' and that this is a trend that will prevail. The meat and dairy sector need to not view this as a threat to their current business but rather as an opportunity. Instead of considering plant-based proteins as a separate sector, the incumbents could embrace the trend, and reposition their organisation as a producer of 'Protein' not just meat and dairy. This strategy would allow them to develop new business models and to diversify their business offering with a view to building long-term resilience.

In 2022, as one of the first traditional dairy based brands, Friese Vlag introduced the plant-based alternative for coffee milk; barista haver. That product was followed by the plant-based chocolate milk in 2023. Obviously the brand name helps in achieving consumer confidence, and ' going plant-based', significantly improves the 'green image' of the brand[142].

142 Friesche Vlag komt met plantaardige Barista Haver (foodclicks.nl)

Recommendations for Irish government

Be a champion for new ambitious EU sustainability regulations

Currently Ireland is a key player in the European meat and dairy processing sectors, which are sectors with large challenges when it comes to realising sustainability goals. . As the EU moves towards a more unified approach to food systems sustainability, compliance with new regulations will be crucial to remain at the forefront. The Irish government can play a key role in maintaining its position as a meat and dairy exporter if it stays on top of new regulations and starts implementing these sooner rather than later, in order to give its producers and processors an advantage once the regulations are passed. Moreover, active engagement of the Irish government in shaping ambitious EU policy is helpful to meet their national environmental targets and establish a level playing field with the rest of Europe.

Enable inclusive decision processes for a Just Transition

Ensuring that the principles of the Just Transition (see Chapter 5) are met when engaging with processors and primary producers is essential for the transformation of the food sector. The government is uniquely positioned to coordinate between the EU at the highest level, all the way along the supply chain to the primary producers. It can play a key role in letting primary producers' and processors' voices be heard at higher levels. Understanding local challenges and representing the interests of civil society is important to ensure that producers and processors feel included in the process and support changes being implemented. Yet primary producers require targeted support in their interactions with food processors, as they can be highly vulnerable to fluctuations in the market.

Pre-Competitive Collaboration & Robust Sustainability standards

There are a handful of big players in the meat and also in the Dairy. It is sub-optimal that all of them are doing their own thing – we need to get them to work together agree on a single framework for the meat/dairy farmers and also the price premium to pay to really scale this up and prevent gaming by farmers/other stakeholders. The government can look to convene/encourage this type of collaboration along with Origin Green as everything needs to be aligned and included in the sustainability standard.

In addition, there is a high risk of industry capture and lobbying through the reserved access offered by pre-competitive collaboration, so more transparent and coordinated oversight would be beneficial to aligning these processes with ambitious national goals[143]. As mentioned in the chapter on Just Transitions, the government can reduce this risk by supporting governance initiatives which rebalance power between producers and offtakers, such as local food councils, and establishing new localized markets using digital technology. Producers again have a strong role to play in providing price protections for sustainable producers, price disincentives for unstainable producers. These initiatives must go hand in

143 https://www.msi-integrity.org/not-fit-for-purpose/

hand with a concerted effort to empower farmers, both economically and culturally. Initiatives, whether private or public, should be based around learning, building peer-to-peer networks and inclusion, to improve the socio-cultural value of farming as a profession.

Steer ambition in the private sector with science-based targets, tools, and guidance

Processors play an important role in enabling producers of meat and dairy to implement more regenerative and sustainable practices. Many companies are currently investing in programs to achieve environmental goals, but it is too early in the progress of these programs to accurately evaluate their success. However, some common shortcomings are already recognizable. For example, the focus on climate/carbon rather than holistic sustainability approaches, and the focus on per kg efficiency gains, which often results in net emission gains due to market share increases. If the indicators used and targets set do not accurately represent scientific knowledge on what needs to change, these programs will not contribute to positive environmental outcomes.

Governments have an important role to play in steering ambition with the private sector to align on science-based frameworks and targets. The use of national- and/or sector-aligned tools and frameworks can steer ambition and enable stacked impacts. The Biodiversity Monitor for Dutch Dairy Farming is a good example of a science-based tool which allows for multiple actors across the value chain to work towards the same targets and also to stack financial rewards. Governmental institutions such as DAFM can play a key role in enabling collaboration among meat and dairy processors to develop such tools and steer ambition. Moreover, engaging with companies in such initiatives allows the government to evaluate the impact of corporate-led initiatives and ensure that their outcomes, at the aggregate level, lead to the achievement of national environmental goals.

Look beyond the primary producers; innovate in the production chain.

Strange enough, in a chapter discussing the role of the processors in the dairy and meat chain again a lot of attention is given to the primary producers. Which makes sense, as the main GHG emissions origin in the primary production. Still significant reduction of GHG emissions can be gained higher in the chain, by applying circularity principles for energy (including heat) and water, implementing recent innovations in machinery, adoption a packaging strategy aiming a minimizing plastic use, whilst maintaining food quality standards and broadening the business model, for instance including the alternative, plant based, proteins into the portfolio of products.

6. Just Transition Approaches

Authors:

Willow Sommer | Alexandra Fox

Credit: Shutterstock

Acknowledgements

Metabolic would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Willow Sommer (Metabolic) and Alexandra Fox (Metabolic)

Reviewers

Saskia Visser (EIT Climate KIC), Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC)

How to cite this Chapter:

Metabolic (2023). Just Transition Approaches. Chapter 6 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector

Just Transition Approaches

What does a Just Transition look like for the Irish Agri-Food sector? The term stems from the coal and energy industry, which was heavily affected by widespread coal mine closures and also more recently by the shift to renewable energy. Take the example of the UK, where in the 1970's mine closures put huge numbers of people out of work virtually overnight, leaving widespread economic decline and the destruction of communities.

Historical examples indicate what not to do, and lessons have been drawn from the absence of a just transition. There are now institutions in place at the European level to support the people undergoing socio-economic transformation in the context of the transition to a climate neutral economy. Financing for the Just Transition tends to be oriented towards the energy sector: to *compensate for negative consequences*. The transition in agriculture is more nuanced, but for that reason perhaps more difficult (Baldock and Buckwell, 2021). The transition to a carbon-neutral agrifood sector is rather an opportunity to restructure a sector which has been marked for too long by undesirable social, economic and environmental outcomes.

Agriculture is a critical part of the Irish economy and farming a part of many Irish peoples' livelihood and cultural identity. The sector is a boon to Ireland's economy, responsible for 10% of exports and 7% of modified GNI.[144] However, agriculture is one of the most unequal sectors in Ireland, with many farmers facing 'severe poverty' (McCabe, 2020). Out of the ~137,500 farms in Ireland, 29% are considered economically vulnerable and 37% were in debt in 2021. The average age of farmers is 59 years old, and young people are more often not eager to carry on with this essential profession. In the meantime, consumers feeling economic pressure from inflation and international crises do not feel they can spend more on food. Primary producers, those we call farmers, are both those most vulnerable to changes associated with climate change, and the actors with the most direct influence on the transition. Changes in the way primary producers work with the land will ultimately dictate the long-term environmental and social outcomes for the sector.

Amidst these challenges, the sector is undergoing a transformation. The Irish government has committed to numerous climate related targets [see Ch. 1], and a Food Vision of an integrated, environmentally sustainable, and socially rewarding agrifood system has been set for the year 2030. The Food Vision takes a Food Systems Approach, addressing the entire value chain from producer to consumers. The agricultural sector provides jobs for the broader community, especially in rural areas, including shopkeepers, butchers, bakers, creamery, and abattoir employees. While it is the interaction between all stakeholder groups which will ultimately sustain the transformation to a carbon neutral sector, this chapter on Just Transition focuses on the primary producers, those at the very start of the chain and closest to the land.

144 These statistics include forestry and aquaculture (Government of Ireland, 2021)

Scholars have said, "transition is inevitable, justice is not." (Blattner, 2020) - and while this may be the case for the energy sector, where entire industries are being replaced with those relying on renewables, for the Agrifood sector, the transition relies directly *upon* justice being achieved as an integral part of its process. Compared with the energy sector, whose transition is characterized by complete shutdowns and large concentrated companies with many employees, the Agrifood sector is defined by many small and micro family businesses which will be required to change their production and business models, rather than shutting down completely (Baldock and Buckwell, 2021).

Learning and implementing more regenerative and sustainable agricultural practices takes time, skills, and sometimes requires a change in the technologies used on the farm. All these inputs require investment and come with switching costs. Thus, if justice is not achieved, i.e., if these barriers are not overcome, primary producers will not be able to transition. If Ireland's primary producers are not engaged in a fair and empowering way, the trends in declining numbers of farmers will continue, and consumers will be left to rely on imports from a global market vulnerable to increasing shocks, threatening food security (Zmija et al, 2020). Addressing these overarching challenges to implementing the transition will both contribute to delivering justice to primary producers, and to enabling the environmental outcomes required by the transition. There is no transition without justice for primary producers.

Just Transition is a complex concept, and its definition is at once broad and hard to pin down. Many organizations and academics in the space have established principles, frameworks, and definitions, but it is commonly accepted that how it looks in practice and implementation must be dictated by the context at hand. This chapter dives into some of these frameworks and principles, distilling them to the dimensions of justice at their core, as these are their necessary basis. The trends present in the Irish agrifood sector are analysed through this lens, assessing the challenges and identifying the opportunities that can be drawn from them. Best practice case studies are included as inspiration for how justice in transition is being pursued in similar sectors around the world. Then, recommendations are given for policy makers in Ireland to set their sights upon as they pursue the governance of a Just Transition for the Irish Agrifood sector.

This chapter takes the following structure:

- Review of frameworks on Just Transition and their application to the Agrifood sector in Ireland
- Overview of trends and challenges to a just transition in the Irish Agrifood sector
- Seizing the opportunity to make a just transition: recommended intervention areas for the Irish Agrifood sector
- Best Practice case studies from around the world
- Conclusion & Recommendations for Just Transition in the Irish Agrifood Sector

6.1 Review of frameworks and definition

A multitude of frameworks to guide policy makers in implementing a just transition exist. We've reviewed four framework principles alongside scientific literature for the purpose of this chapter. The annex provides a list of these four sets of principles provided by research organizations and NGOs. While these sets of principles were practical and operationalizable, they were focused at the high level and mostly did not consider the specific challenges of the food system and agrifood sector. The review is summarized here before introducing the framework that was used to guide this chapter.

The most authoritative source in this field is the International Labour Organization (ILO) which provides guidelines for a just transition that puts human rights at the center of the concept. ILO and Stockholm Environment Institute (SEI) keep their principles general and applicable to any sector while ActionAid and the Institute for European Environmental Policy (IEEP) provide guidelines specific to the agrifood sector. The IEEP are designed to fit the EU context, making them more relevant to the Irish context. Despite these differences, there is significant overlap in the content, such as stakeholder involvement, creation of enabling environments and fair distribution of benefits. These principles are all relevant to the just transition and should be considered when seeking high-level guidance on policy decisions.

For this report we will rely on the science-based framework outlined by Tribaldos and Kortetmäki (2022) that considers the complexity of the food system and how to assess its specific transition requirements and outcomes. It unpacks the just transition in food systems based on an understanding of social justice as a whole and what dimensions constitute justice, leading to a clear list of criteria to assess the justness of a transition. The framework is built upon the six dimensions of justice, drawn from synthesis of several different theories of justice. The dimensions are introduced individually below to enable a better understanding, but in reality they are deeply intertwined. They build on each other and the strongest interventions target several dimensions at once. A holistic view is central to understanding justice in transitions. Many focused interventions may only target certain dimensions, but the overarching just transition plan must address all six dimensions. Table 6.1 provides an overview over the dimensions of justice introduced here, and the graphic below illustrates how the different dimensions are interconnected.

Table 6.11: *The dimensions of justice explained*

Dimension	Definition	Indicator
Distributive	Fair allocation of resources	Economic outcomes
Procedural	Participatory planning process	Inclusion of stakeholders in decision-making structures; diverse knowledge sources
Recognitional	Respect for diverse socio-cultural identities	Socio-cultural values; feeling of well-being and pride in the profession
Capacities	Capacity to adapt to changing economy and society	Availability of training & educational opportunities to primary producers; feeling of agency
Cosmopolitan	Future generations and more distant population groups are not negatively affected by current changes/structures	Future generations and both urban and rural citizens have the same or better opportunities as current generation
Ecological	Accounting for changes in nature such as ecosystem integrity	State of nature outcomes

The three dimensions most commonly discussed in the field of environmental justice are distributive, procedural and recognitional (fig. 6.2). **Distributive justice** refers to a fair allocation of resources and benefits, and thus a parallel sharing of inevitable burdens, among members of society. In the context of the transition, this would entail granting the necessary support to all of those negatively impacted by the transition and reallocating the transition costs according to their ability to pay. This can be achieved through provision of support, both financial, social and educational to those who will have to bear the brunt of effort and cost in transitioning. Especially where those people constitute groups which are already disadvantaged, targeted interventions are required. Indicators of distributive justice thus focus on *outcomes and* can be measured through economic impact and opportunity indicators.

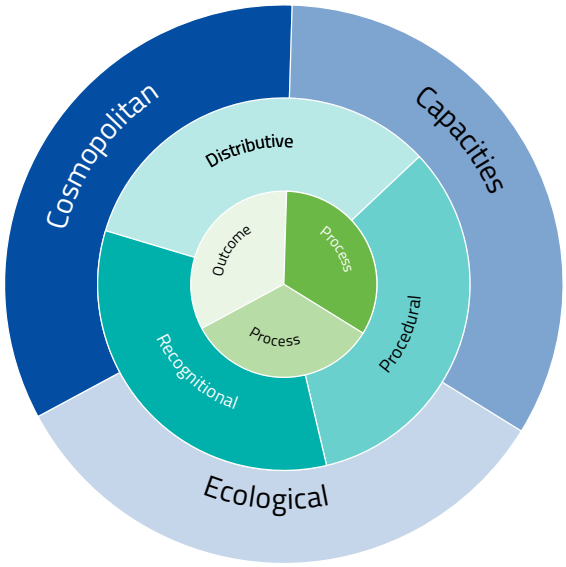


Figure 6.2: *The dimensions of justice that constitute a just transition. Adapted from Tribaldos and Kortetmäki (2022).*

The second dimension of justice is **procedural justice**, which refers to the way decisions are made. In addition to the results of a policy being fairly distributed, the *process* of creating those policies must be participatory, in that they include those most affected by the policies in the decision-making process.

These groups are key stakeholders and must be included in every step of the way. Indicators of procedural justice focus therefore on the processes of decision-making, namely on the inclusion of those actors who are impacted by policies, in their design.

Recognitional justice refers to respecting and acknowledging diverse socio-cultural identities and values. While this dimension of justice is difficult to measure, without it, distributive, and especially procedural justice, will be sought in vain (Ruano-Chamorro, Gurney & Cinner, 2021). Although recognition is ultimately a subjective experience, institutions can be built that support rather than inhibit recognition. Mechanisms to enhance recognition could include acknowledgement for power imbalances and context-specific knowledge in decision-making processes. This dimension of justice is hard to measure and is most evident when it is absent. Where people feel their experience has not been recognized, they will not be satisfied with and can possibly even disrupt, or protest measures taken.

The next three dimensions are the enabling factors to a just transition for primary producers. Without each of these dimensions in place, the more nuanced layers of justice above cannot be reached and sustained over the long time.

The **capacities** dimension takes a complex view of capacity, including not only technical capacities, but also the 'equal opportunities of people to choose and act in diverse ways', based on the theorizing of Amartya Sen. In the context of the just transition for agriculture, this largely intertwines with recognitional and procedural justice, aiming to ensure that primary producers have agency in the decision making around the transition and are reciprocally recognized for all that they are contributing to it. Capacity building will be required for primary producers to transition to practices and business models which can reasonably be a part of the carbon-neutral future of the Irish Agrifood sector. Without the proper awareness raising, engagement, training and ongoing support, these capacities will remain out of reach, and so will the transition.

The **cosmopolitan** dimension of justice acknowledges that if there is no transition, there will be very little operating space for future generations, for developing populations around the world, and for other sectors of society, ie. those who do not grow their own food. This chapter keeps the focus on Ireland today, but it is implicit that the steps to transition taken today are in pursuit of intergenerational justice, ensuring that future generations are not in a worse position than the current generation by implementing changes to the economy, society and environment.

Lastly, **ecological justice** is included as a measure of the interventions going beyond climate change to also include nature-based outcomes, such as changes in biodiversity or water and air quality. This aspect is a relevant measure of justice as societies have always and will continue to rely on nature for its provision of ecosystem services. Undermining this aspect of justice would inherently inhibit a Just Transition, by depleting the resources upon which the economy relies. As the effects of climate change increase, our economy and societies will become increasingly reliant upon the resilience provided by biodiversity and natural systems in order to adapt, thus intertwining ecological justice with intergenerational justice.

As with many complex concepts, there is no one definition of the just transition. The below definition captures our working understanding of the term and its application to the context at hand.

Definition of Just Transition: *The transition refers to the process of Ireland's current economy and society transforming in such a way that climate targets set by the Irish government are met. This process can only be deemed 'just' if the changes undertaken to transition to a carbon neutral economy do not replicate the structures of inequality that currently exist. In order to achieve this, the above six dimensions of justice must be met.*

6.2 Trends relevant to the Just Transition for Agrifood in Ireland

Approaching a just transition looks different in each context, because it must reflect the lives of the people at its center. This section will introduce the trends and opportunities most relevant to achieving equity and justice in the Irish Agrifood transition across the various dimensions elaborated in section 6.1. The dimensions of justice outlined in the framework above underpin the selection of the relevant trends described in the following section.

This section provides a high level synthesized perspective, based on desk research. We've analyzed various existing reports and studies conducted by the Irish government, local multi-stakeholder engagement processes and advocacy groups through the lens of the framework presented above, in order to pull out which trends are likely to pose barriers. Knowing those barriers will enable policy makers and other stakeholders to design and implement solutions that turn barriers into opportunities for justice within a climate-neutral transition. No single opportunity can in itself address all six dimensions of justice, therefore we approached them holistically to support integrated policy-making. Each opportunity is accompanied by a best practice case study to illustrate how this practice is being done around the world. These case studies are compiled in a table in the annex.

Financial insecurity and recapturing value

On average, Irish farmers capture 18% of value added in the economic food chain, which is lower than the EU average of approximately 25% (Government of Ireland, 2019). Without subsidies available in the EU like the CAP, the problem is exacerbated. Primary producers around the world tend to live in poverty because their profit is not proportionate to their amount of work within the food value chain. The power within the value chain is often concentrated downstream, specifically with the offtakers and supermarkets who process and sell food at scale. The transition to a carbon-neutral economy provides an opportunity to redistribute some of the balance within agricultural supply chains, while simultaneously leveraging incentives to facilitate the process of transitioning.

In addition to this unequal profit distribution, primary producers are vulnerable to supply chain shocks. These can be caused by conflicts, natural disasters and other unpredictable events which lead to distortions or interruption of global supply chains. The globalization of the food system has led to a production system aimed at efficiency, where specializing on a certain product in order to grow as much of it as possible has become the default model. This specialization results in input-intensive monocultures and large-scale livestock production. While these production methods are detrimental to the environment, they also put primary producers in the precarious situation of being reliant on a limited number of products. A sudden market fluctuation somewhere along the supply chain will hit the primary producer of that specific commodity and may put their livelihood at risk (Dillon et al., 2022). Climate change exacerbates these vulnerabilities, as unpredictable weather patterns affect the productivity of farms and could cause Irish farmers to lose part of their market share internationally. Financial insecurity faced by primary producers is closely linked to the dimension of **distributive** and **recognitional justice.** Their vulnerabilities arise from an unequal distribution of resources and a just transition is key to addressing such inequalities. Distribution of value along the food chain indicates how different roles are valued by our society. If financial resources were redistributed to more accurately reflect the value of the work that primary producers do, a greater sense of **recognitional justice** might be achieved.

These food systems threats also affect consumers: Both rural and urban consumers rely on primary producers for sustenance in the modern economy. Consumers are used to buying food cheaply, without much knowledge on where and by whom it was produced. Often little thought is given to the complex supply chains they rely on, until they are disrupted. For many consumers the supply chain shocks caused by the COVID-19 pandemic in 2020 and the invasion of Ukraine in 2022 were unprecedented, and exposed the risk of relying on distant lands for basic foodstuffs. Here, the **cosmopolitan dimension** of justice comes into focus: future generations and those that are currently disconnected from the food production system need to be taken into account when restructuring the system. Food must remain accessible to everyone, both during the transition and in the long term.

Additionally, consumers in Ireland face rising diet-related health risks. Ireland now has the 9th highest rate of obesity in the EU, a number that has increased since the pandemic (WHO, 2022). There are numerous complex factors which influence these adverse health outcomes, food is one of the most important. Access to and availability of healthy food choices could help alleviate this problem. Yet, given the complexity of the global supply chains, local primary producers and governments are somewhat limited in their ability to address this barrier to the multiple dimensions of justice (Coulson and Milbourne, 2021). Increased consumer awareness towards supply chain risks and health issues may be one step towards a higher willingness to pay for a secure and healthy food supply closer to home.

Credit: Shutterstock

Opportunity

The status quo is that food should be cheap and easily accessible, driving the perception that farming is a low value job (Zmija et al, 2020). A consumer mindset shift is needed to change this construction. While changing consumer perceptions is a complex challenge, there are numerous concrete leverage points, accessible through private and public actors, which can contribute to a diffuse shift over time, and then perhaps all at once.

Primary producers are disadvantaged within the current food supply chain through many mechanisms that supermarkets and offtakers use to maintain the status quo. The main tool for facilitating relations within the value chain are contracts. Offtakers buy food from primary producers according to contracts which place the burden of risk on the producer. A production management contract involves providing technical assistance to the farmers to enable them to adhere to certain production standards and techniques. Adhering to this type of contract can help build stronger relationships between offtakers and producers, leading to fairer risk sharing arrangements (Chamberlain, 2019). Under such contracts, the offtaker can incentivize more sustainable production methods, while promising a fixed higher price to cover some of the transition costs.

While upstream relationships are shaped by contracts, downstream the value chain is shaped by transactions: shopping and consuming food. Bringing consumers closer to primary producers, through local farmers' markets, community supported agriculture schemes and agro-tourism is likely to increase awareness of the value of farming, while also providing complementary sources of income for farmers. These initiatives can also act as tools for realizing **cosmopolitan justice** by including consumers in the food system as more than simply customers and giving them more agency over where their food comes from.

Diversification offers another opportunity for greater financial security. When primary producers do not rely on one export market or buyer, they reduce their vulnerability to price or market fluctuations. Of the 42% of farms that are viable in Ireland, half rely on a supplementary off-farm income source (52.5% in 2019). On and off-farm diversification can serve to make primary producers more resilient to the changes inherent to this transition period, and can also generate co-benefits for the environment in some cases. One of the tools governments have at their disposal for supporting this are schemes for payments for ecosystem services/nature. This can be implemented in the form of land restoration projects, forestry management, or soil regeneration, where farmers spend their part time work on nature rehabilitation projects which are remunerated by public programs. This type of work can also be included in private contracts where offtakers use land rehabilitation to meet their net zero carbon commitments. All of these tools naturally contribute to the ecological dimension of justice. Other ideas for diversification include:

- On-farm diversification (intercropping, crop rotation)
- Agro-tourism & value-added products
- Geographical Indication Certification
- Community supported agriculture (CSAs)
- Accessing new markets: local food markets/stores/digital apps

Another major lever which is relevant to Ireland, where 37% of farms are in debt, are programs for debt-forgiveness. This can be leveraged as a tool to incentivize transition, through schemes such as "debt for nature" swaps. This is a financing tool that is targeted to offer loan forgiveness and cost-saving in return for on and off-farm land rehabilitation or nature conservation activities. This tool addresses the just transition explicitly, by covering transition costs and can even be seen as retribution for past misleading incentives. For example, 63% of dairy farmers in Ireland are in debt for investing in the intensification methods which were previously promoted, and that they will likely have to dial down (Buckley & Donnellan, 2022).

Besides addressing primary producers' incomes and therefore **distributive justice**, these opportunities are also relevant to the **capacities dimension** of justice. By encouraging primary producers to diversify their on- and off-farm operations, their farms will become more resilient and adaptable to change. New skills and agency over what path to take towards diversification will contribute to a stronger capacity to adapt to change in the long run.

Case studies:

Accessing new markets through digital technology

- A mission-driven company, Tanihub has helped connect over 100,000 smallholder farms in Indonesia to consumers since 2016. The app simplifies interactions between producers and customers using modern technology that is available to anyone with a smartphone.

Source: https://tanihubgroup.com/thg/wp-content/uploads/2022/04/thg_company_profile.pdf

- The son of a 6th generation dairy farming family is connecting the business to new markets. Joost set up an unmanned shop in the Leiden (Netherlands) city center that sells value added products and produce from a collection of local farms. An app allows you to access the shop and pay for what you buy - saving farmers time and money while still reaching more urban consumers.
- Dimension of justice: distributive, recognitional, cosmopolitan, capacities

Source: https://www.oogst.shop/winkels/leiden

Community Supported Agriculture (CSA) in France

- CSA was born out of the confluence of farmer autonomy and conscious consumers and now feeds 400.000 consumers in France. The model works via a contract-based direct selling system that ensures a stable income for primary producers. Decision-making is shared between producer and consumer and the national CSA association allows for knowledge sharing. All farms employ agro-ecological practices which make the production sustainable and provides consumers with healthy choices. This type of local farming model already exists in Ireland but could be scaled up through a supportive policy environment.
- Dimensions of justice: distributive, recognitional, cosmopolitan, capacities, ecological

Source: https://www.accesstoland.eu/IMG/pdf/overview-of-community-supported-agriculture-in-europe-f.pdf

Embracing regional diversity

Agriculture in Ireland is characterized by a regional diversity that is determined in many ways by the land itself. It is well known that some Irish farms are more profitable than others. In the Southern region, 43% of farms are considered viable, compared with 37% in the Eastern and Midland region, and only 18% in the Northern and Western regions (Government of Ireland, 2019). This discrepancy can be explained largely by the fact that dairy and arable farms result in much higher farmer incomes on average when compared to sheep and cattle farms (Buckley & Donnellan, 2022). Where the type of land dictates the type of farming practiced, it also dictates the potential that a sustainable transition brings. These regional differences can inhibit distributive justice, if they are not accounted for in the planning process.

If those less viable farms are operating on degraded lands, for example in the west, there is greater potential to benefit dramatically from land regeneration conducted as part of the carbon-neutral transition. On the other hand, dairy farms have an outsized impact across all environmental impact indicators (GHG, nitrogen excess, phosphorus excess and ammonia emissions) and tend to be concentrated on the more productive lands in the southern region.

Thus, the south has more productive lands, but is facing increased agricultural pollution as a result of intensified dairy production and herd increases. Each farm type will face different costs and benefits in the transition, depending on a multitude of factors such as the financial situation they are in to begin with, the scale of changes required from them and the state of the land that they are working. While dairy farms have the highest income per hectare, they also have the highest incidence of farm debt (66% compared with 40% across all farm types in 2021 (Buckley & Donnellan, 2022)). While some farmers struggle to reach viability, other farmers, specifically those specializing in dairy production have higher incomes but will face increasing debt along with a more urgent need to invest in changing practices to reduce their environmental impacts. Interventions can therefore not be rolled out as a blanket approach, but must be tailored to a region's specific needs.

Opportunity:

Different regions face differing challenges. The opportunity here lies in capitalizing on that diversity, rather than minimizing it. Diversity is the foundation of resilience and brings richness to culture. It is important then to disaggregate national indicators and data, not only by farm type, but also by spatial distribution, making the concentrations and gaps visible on the map. Then strategies can be formed according to more holistic and place-based realities. Accounting for these existing barriers to **distributive justice** will make interventions more targeted and lead to fairer economic outcomes. A holistic approach to rural development is already set forth in Ireland's Rural Development plan: Our Rural Future (Government of Ireland, 2019), it would be wise to regionalize these planning processes and link these regionalized plans to spatial and environmental analysis of the land and its regeneration potential. By

tailoring these approaches to their specific contexts, the **ecological dimension** of justice is also more likely to be addressed successfully, since differing natural conditions will respond differently to interventions.

Case study: Local taskforces for just transition in Scotland

- Scotland is a front-runner when it comes to just transition plans in policy. It has a Just Transition Commission in place which advises the government. In addition it has deployed local taskforces in the past to support the community on the ground and make their voices heard. This was successfully implemented when a mine closure affected a specific community. A taskforce that includes community representatives who are familiar with local contexts will be more effective in finding solutions that work locally and will make the community feel more represented.
- Dimensions of justice: procedural, recognitional

Source: http://files.nesc.ie/nesc_research_series/Research_Series_Paper_15_TTCaseStudies.pdf

Fora for inclusion and social dialogue between policy makers and stakeholders

The number one ingredient for successful multi-stakeholder processes is trust, thus its absence becomes a barrier to a just transition. **Procedural justice** refers to the inclusion of all relevant stakeholders in planning processes, and arguably the most relevant in this context are primary producers. In the stakeholder engagement workshop conducted by Climate KIC, primary producers expressed frustration at the feeling that they were being hyper-criticized. They feel that there is an outsized focus on the emissions from the agriculture sector, and not enough attention to the effort that primary producers are putting into transitioning their practices or the progress they've made. These feelings indicate that primary producers perceive an absence of **recognitional justice.** There are clear efforts from the Irish government at establishing these fora for inclusion of primary producers, but the reception risks falling flat. The AgClimitise plan incorporates a 'Future of Farming in Ireland Dialogue', which aims to bring farmers, scientists, environmentalists and social groups to find practical solutions for a just transition in agriculture. Despite good intentions, the globalization of unequal power dynamics limits the influence that national actions can have on this feeling. For example, the processes surrounding the development of the Common Agricultural Policy and its reform at the EU level are subject to the power of vested interests and entrenched political dynamics (Coulson & Milbourne, 2021). Even if the root cause is out of reach, acknowledging these power dynamics within any attempt at dialogue can help assuage feelings of frustration (Brouwer et al., 2015).

Distrust is further stirred by changing requests from policy makers. If the agricultural transition in Ireland is to occur, primary producers must not only be actors in the process of policy making, but they must be actors who can claim agency within that process. First, farmers were encouraged and incentiv-

ized to make their production more efficient and intensive. Herd sizes increased and debt was procured, only to now hear that this may have been the wrong direction. Especially if farmers feel left out of the decision making processes that produce these turns, this can lead to increasing levels of distrust and eventually even conflict. The example of the Netherlands provides a warning in that sense, with farmers taking their tractors to the streets to protest decisions they felt left out of. The level of distrust with the government became so high that inclusion in official dialogue, once it finally came, did not suffice.

Opportunity:

A Just Transition for the Agrifood sector demands dialogues at multiple levels and between stakeholders all along the value chain in order to meet the requirements of **procedural justice**. In addition to including primary producers and other actors within the food value chains in dialogue with policy makers, consumers should have more opportunity to engage with primary producers. Encouraging their engagement in these dialogues positively contributes to the **cosmopolitan dimension** of justice by connecting perspectives that are often separated by increasingly extended value chains. Citizen's assemblies and co-governance structures can become fora for exchange between stakeholders so that understanding of the challenges spreads and more systemic solutions are reached. Supporting these fora can have numerous benefits across the dimensions of justice. More collaborative interaction between consumers and producers, in addition to that garnered through local food markets and community supported agriculture schemes, builds those implicit social and cultural currency which are necessary to just transition: care and trust.

Case Study: Co-creative governance in Ghent, Belgium

- The city of Ghent has a food council that consists of many different stakeholders, including primary producers, knowledge institutions and civil society. The council functions as a permanent advisory body to the government and is also involved in the implementation of projects on the ground. It has its own budget and forms independent opinions. The local scope and the inclusion of primary producers in the council makes the solutions suited to local contexts, while also ensuring that the producers have a say in decisions that will affect the way they are expected to grow their produce. Disagreements can be addressed early on in the process, rather than later to avoid that everyone's concerns are accounted for in the policy-making process.
- Dimensions of justice: procedural, cosmopolitan, recognitional

Source: https://stad.gent/en/city-governance-organisation/city-policy/ghents-climate-actions/sustainable-food

Sector demographic and attractiveness of the profession

The average age of primary producers in Ireland is 59, indicating that not many young people are entering the profession. An in-depth study by Foundation for European Progressive Studies and The Think Tank for Action on Social Change in Ireland (TASC) revealed numerous causes to this demographic trend, including the disintegration of rural services, indebtedness, increasing overheads and unsustainable workloads due to intensification and the vulnerability of farm incomes and rural outmigration (McCabe, 2019). Ireland's Rural Development Policy 2021-2025, "Our Rural Future" sets forth a strategy for addressing these fundamental barriers. The strategy looks at the needs of primary producers within the context of the rural communities where they often reside. This integrated approach is also key to ensuring that young people in those communities, and perhaps within farming families, will be interested in taking on the profession themselves. There is a gender bias within the farming profession, where only 14% of employees in the sector (incl. fisheries and forestry) are women - leaving an entire half of the population relatively unengaged. This challenge inheres a huge opportunity to support, highlight and promote women farmers and inspire the next generation.

Beyond the lack of interest of rural youth towards farming, other population groups are also highly disconnected from the agrifood system. Most urban citizens buy their food in supermarkets and have limited awareness of the labor and time invested in these products. The high demand for animal products is in a large part responsible for the emissions related to livestock farming and cannot be ignored in this context. Consumer awareness towards the impact of food choices and the struggles of primary producers must be increased in order to ensure the whole population supports policy decisions aimed at a more environmentally friendly sector in which the farmers are supported by the government rather than shouldering the risk all alone.

These trends exemplify the lack of **recognitional justice** that primary producers seem to be facing. They are the holders of an extensive wealth of knowledge essential to all human beings and yet often don't feel valued by those that depend on them. A just transition must therefore address this specific dimension of justice through a nuanced approach that targets the way the rest of society interacts with the agricultural sector.

Opportunity:

Nuanced communication in national channels and media about the effort and progress primary producers are making in the transition to a carbon-neutral sector can help change the image of the sector among consumers and young people across society. Education is another channel for shaping the image of the agricultural profession. The use of modern and sustainable farming techniques in conjunction with digitalization is likely to contribute to a significant change of image for agriculture. By demonstrating that new agricultural approaches are in use and bringing about business opportunities, youth are more likely to show an interest in farming (Leavy & Hossain, 2014). Rather than a subsistence-based activity, it will be viewed as a business opportunity and more desirable employment sector. This shift is especially important for increasing young people's interest in the field, which

has been historically low in recent years. The cooperation with local schools can also contribute to this mindset shift as it presents the most direct path to informing the youth. Starting with primary education, children can learn more about where their food comes from through farm visits and school gardens.

This education can extend beyond rural areas in order to include urban citizens that are generally disconnected from the agricultural sector. By providing them with information and opportunities to broaden their knowledge and maybe even experience life on the farm (e.g. regular school field trips) the divide between urban and rural populations can be bridged. Closing the urban-rural gap via these kinds of programs can contribute to **cosmopolitan justice**. By bringing distant population groups to farms, they are likely to feel more connected to the food production system and may become more keen on participating in multi-stakeholder workshops around the transition process. This increases the **capacities dimension** of justice on the consumer side. Many urban and rural consumers have lost agency over the abilities and awareness needed to lead a healthy lifestyle through their relationship to the food they eat.

Case Study: Innovative collaboration with local schools in the Philippines

- This project in the Philippines supplied a local school with Information and Communication Technology (ICT) devices and access to online knowledge bases. The children used the devices to research common problems faced in agricultural production and relayed this information to their parents. At the same time they developed an interest in agriculture and said they were more likely to work in this sector than they had been before. Children in Ireland could instead be tasked with researching sustainable production methods, which may spark their interest in this type of farming. Linking agriculture to technology and developing both skills simultaneously will make the younger members of society more technologically literate while also sparking their interest in farming.
- Dimensions of justice: recognitional, cosmopolitan, capacities

Source: https://www.igi-global.com/chapter/the-infomediary-campaign-in-the-philippines-as-a-strategy-to-alleviate-information-poverty/134261

Respecting diverse knowledge systems

Market-oriented or internationalized technical knowledge can give primary producers the edge to compete in today's globalized economy. For this reason it has been promoted and prioritized, especially in the years since 2015 when the EU Milk Quota was lifted. Intensification and modernization of farming practices has been the focus. While there is surely a place for these techniques, respecting more diverse land-use models and place based knowledge can help to bring the system back into balance. The primary producers, especially those whose farms are more long-running and less 'modern' have a longstanding cultural connection to the land and animals (from Climate KIC Deep Demo workshop #1 p. 7). Trust and collaboration is also fostered through respect for the diversity of knowledge and experience residing within the farming community.

Knowledge about soil health is an ideal place to bridge the gap between knowledge systems. Soil is the foundation of a healthy and sustainable agricultural sector, and primary producers are the custodians of that soil. The growing body of scientific and technical knowledge on this subject can provide useful frameworks and starting principles to guide farmers in their exploration of their own soils' health and the practices that support it. Soils are site specific, meaning knowledge and practice must be built over time, ideally through an adaptive learning approach. Although international communities of research and technology recognize the importance of agricultural soils in the transition to a carbon-neutral and biodiverse world, they are continually mystified by their complexity. The risk here is that primary producers are further alienated and diminished by technical experts sharing knowledge unidirectionally. Indeed, farmers are turning more and more to online knowledge generated by their peers, often through farmer knowledge networks or even through social media (Rust et al., 2021). Being attuned to this shift when exchanging knowledge about transition measures can be the difference between collaborative support and disruptive discontent.

Opportunity

Supporting farmer knowledge sharing networks is a tool with multiple co-benefits, also for social well-being of individuals in the farming profession, which can often be isolating. Building knowledge communities in turn makes the sector more professionalized and attractive to young ambitious students and creates a culture of innovation. As such, these interventions will also contribute to improving perceived **recognitional justice:** the primary producers are knowledge holders in these networks and receive recognition for their skills. Lastly, knowledge sharing can be a key tool in building the **capacities dimension** of justice, which is based on skills to allow farmers to adapt to changes.

Case Study: Innovative Farmers Network in the UK

- The Innovative Farmers Organisation was established in order to allow farmers to conduct their own field research and adapt their farming practices accordingly. An example is a trial that 5 farmers conducted on using buckwheat to control the amount of couch grass growing in their fields, rather than using traditional methods that are detrimental to the soil. The experiment proved successful and even led to increased yields. These learnings are then added to the organisation's website, which other farmers can draw from. Sharing the lessons enables a knowledge exchange among farmers, which increases the likelihood of others adopting innovative methods, especially since they are more likely to trust their peers.
- Dimensions of justice: recognitional, capacities, ecological

Source: https://innovativefarmers.org/case-studies/tackling-couch-grass-with-buckwheat/t

6.3 Conclusion & Recommendations for Just Transition in Irish Agrifood Sector

If Ireland is to achieve a just transition, justice will have to become an inherent part of the future economy. There will be no need to emphasize the just transition because it will be understood that the objective of this transition is to achieve greater justice within society, in part through shifting away from ecologically damaging activities such as anthropogenic greenhouse gas emissions. The 6 dimensions of justice presented in this chapter provide a framework for identifying the necessary components of that transition, and they should be pursued holistically, because they build upon each other. The absence of one dimension can cripple the others.

The recommendations for policy makers are thus outlined as systemic interventions, objectives to bring forth a transformed agrifood sector:

Local food networks connecting consumers and producers

- Irish consumers need access to healthy produce and producers need markets for diversified crops (those not for export).
- Using and supporting Community Supported Agriculture as a tool for developing these connections has multiple co-benefits: building consumer/producer relationships, mutual trust and understanding; improving social sustainability within agriculture and contributing to rural communities.
- Promoting local food networks can be part of a broader strategy for Rural Development in Ireland, aimed at regenerating rural communities and creating new opportunities within these spaces.
- Local food networks address the distributive, recognitional, cosmopolitan, ecological and capacities dimensions of justice

Empowering farmers through regenerative practice

- Transitioning to environmentally sustainable practice allows primary producers to learn more about their land, building site-specific soil knowledge and sharing and exchanging that knowledge with fellow farmers.
- As society transitions to an environmentally conscious and carbon-neutral economy, production contracts and supply chains should reflect this transformation. Governments should support farmer groups and collectives in negotiating better price guarantees from offtakers and supermarkets. Private actors should transition to production management contracts which reward producers based on their practices rather than yields, and thus support them in taking on new practices.
- Financial security for the vital production of food will be a given. The government can support this by addressing farmer debt through debt for nature schemes, and providing training on sustainable practices. Farmers themselves should be incentivized and supported to diversify their on-farm income through crop rotation and intercropping, and through new ventures such as agro-tourism and exploring value added products and geographical indication certification.
- These taken together, will reposition farming as a forward looking, environmentally sustainable and economically viable profession, inspiring the next generation and promoting a culture of learning and innovation.
- Regenerative practices contribute to the ecological, recognitional, distributive and capacities dimensions of justice

Justice within carbon-neutral transition processes

- Inclusion is a principle at all levels of policy. Primary producers are present at the start of processes and feel agency in the process.
- Local task forces are established across all regions to gather nuanced perspectives and build region-specific plans for the transition's implementation.
- Citizen assemblies or local Food Councils provide fora for social dialogue across sections of society. Consumers and producers exchange and understand each others' position. These assemblies are consulted by policy makers and have the opportunity to take decisions within the communities where they are active. They are trusted as advisory bodies and citizens feel their voice is represented and there is space for dialogue and debate.
- Support is given especially to women farmers who are underrepresented. They are given a platform in order to inspire young women to join the profession where desired.
- Justice within transition processes addresses the procedural and recognitional dimensions of justice.

6.4 References

- Action Aid (2019). Principles for a Just Transition in Agriculture. Retrieved from https://actionaid.org/sites/default/files/publications/Principles%20for%20a%20just%20transition%20in%20agriculture_0.pdf
- Atteridge, A. and Strambo, C. (2020). Seven principles to realize a just transition to a low-carbon economy. SEI policy report. Stockholm Environment Institute, Stockholm.
- Baldock, D. and Buckwell, A. (2021). Just transition in the EU agriculture and land use sector. Institute for European Environmental Policy (IEEP).
- Blattner, C. (2020). Just Transition for Agriculture? A Critical Step in Tackling Climate Change. *Journal of Agriculture, Food Systems, and Community Development*, 1–6. https://doi.org/10.5304/jafscd.2020.093.006
- Brouwer, H., Woodhill, J., Hemmati, M., Verhoosel, K., & van Vugt, S. (2015). The MSP Guide: How to Design and Facilitate Multi-Stakeholder Partnerships. Practical Action Publishing; Wageningen University and Research, CDI.
- Buckley, C. & Donnellan, T. (2022). Teagasc National Farm Survey 2021 Sustainability Report. Agricultural Economics and Farm Surveys Department, Rural Economy and Development Programme, Teagasc, Athenry, Co. Galway, Ireland. Retrieved from https://www.teagasc.ie/publications/2022/national-farm-survey---2021-sustainability-report.php
- Chamberlain, W. (2019). Smallholder Farmer Support Analysis Part 2: Theory of Change – Business model design for smallholder farmer support. RVO.
- Coulson, H., & Milbourne, P. (2020). Food justice for all?: searching for the 'justice multiple' in UK food movements. *Agriculture and Human Values 2020 38:1*, 38(1), 43–58. https://doi.org/10.1007/S10460-020-10142-5
- Dillon, E. et al. (2022). Situation and Outlook for Irish Agriculture. Agricultural Economics and Farm Surveys Department, Rural Economy and Development Programme, Teagasc, Athenry, Co. Galway, Ireland. Retrieved from https://www.teagasc.ie/media/website/publications/2022/Situation-and-Outlook-for-Irish-Agriculture---September-2022.pdf
- European CSA Research Group (2016). Overview of Community Supported Agriculture in Europe. Retrieved from https://www.accesstoland.eu/IMG/pdf/overview-of-community-supported-agriculture-in-europe-f.pdf
- Government of Ireland (2019). Our Rural Future. Rural Development Policy 2021-2025. Retrieved from https://www.gov.ie/pdf/?file=https://assets.gov.ie/132413/433aebac-f12a-4640-8cac-9faf52e5ea1f.pdf#page=73
- Government of Ireland (2021). Food Vision 2030. A World Leader in Sustainable Food Systems. Retrieved from https://www.gov.ie/ga/polasai/b2a3c-food-vision-2030-a-world-leader-in-sustainable-food-systems/#:~:text=The%20Food%20Vision%202030%20Strategy,processing%20and%20the%20equine%20sector).
- International Labor Organization (2015). Guidelines for a just transition towards environmentally sustainable economies and societies for all. Geneva. Retrieved from https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_432859.pdf
- Leavy J., & Hossain, N. (2014). Who Wants to Farm? Youth aspirations, Opportunities and Rising Food Prices. Institute of Development Studies. doi:10.1111/j.2040-0209.2014.00439.x
- McCabe, S. (2020). The People's Transition: Community-led Development for Climate Justice. Foundation for European Progressive Studies: Brussels. Retrieved from https://feps-europe.eu/wp-content/uploads/downloads/publications/feps-tasc_the_peoples_transition_-_2020.pdf
- Ruano-Chamorro, C., Gurney, G. G., & Cinner, J. E. (2022). Advancing procedural justice in conservation. *Conservation Letters*, 15(3), e12861. https://doi.org/10.1111/CONL.12861
- Rust, N. A., Stankovics, P., Jarvis, R. M., Morris-Trainor, Z., de Vries, J. R., Ingram, J., Mills, J., Glikman, J. A., Parkinson, J., Toth, Z., Hansda, R., McMorran, R., Glass, J., & Reed, M. S. (2022). Have farmers had enough of experts? *Environmental Management*, 69(1), 31–44. https://doi.org/10.1007/S00267-021-01546-Y/FIGURES/1
- Tribaldos, T., & Kortetmäki, T. (2022). Just transition principles and criteria for food systems and beyond. *Environmental Innovation and Societal Transitions,* 43, 244–256. https://doi.org/10.1016/J.EIST.2022.04.005
- World Health Organization (2022). WHO European Regional Obesity Report 2022. Copenhagen: WHO Regional Office for Europe. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/353747/9789289057738-eng.pdf
- Zmija, K., Fortes, A., Tia, M., Sumane, S., Ayambila, S. N., Zmija, D., Satola, L., Sutherland L.A. (2020). Small farming and generational renewal in the context of food security challenges. Global Food Security, 26, https://doi.org/10.1016/j.gfs.2020.100412

6.5 Annex: Just Transition principles from various organizations

1. **Action Aid:**
    i. Address - and not exacerbate – inequalities
    ii. Transform the food system to work for people,nature and the climate
    iii. Ensure inclusiveness and participation
    iv. Develop a comprehensive framework

2. **ILO Guidelines for a just transition**
    i. Social consensus, consultation with all relevant stakeholders
    ii. Labour rights must be respected and promoted
    iii. Gender dimension must be considered
    iv. Enabling environment for all actors to drive the transition must be created by policy across economic, environmental, social, education/training and labour portfolios
    v. Policies need to include the just transition component in order to create better jobs for all
    vi. Policies and programs need to be country-specific
    vii. International cooperation must be considered to reach just transition

3. **IEEP Just Transition in the EU agriculture and land use sector**
    i. Enhanced engagement with the farming and land managing communities;
    ii. Preparatory, analytical and supportive work;
    iii. Building knowledge, skills and capacity;
    iv. Fair terms and fair prices for farmers in the food chain;
    v. Developing new income streams and markets for sustainable activities;
    vi. Better use of CAP basic payments to support greater environmental sustainability;
    vii. Targeted supplementary transition aid;
    viii. Fairness between Member States: aligning the distribution of the CAP budget with the requirements of transition;
    ix. Fairness for rural communities;
    x. Fairness amongst consumers

4. **Stockholm Environment Institute**

    i. Actively encouage decarbonization.
    ii. Avoid the creation of carbon lock-in and more "losers" in these sectors.
    iii. Support affected regions.
    iv. Support workers, their families and the wider community affected by closures or downscaling.
    v. Clean up environmental damage, and ensure that related costs are not transferred from the private to the public sector.
    vi. Address existing economic and social inequalities.
    vii. Ensure an inclusive and transparent planning process

5. **Irish Commitments and Plans**

Non-exhaustive collection of national level policies where Ireland has already committed to a Just Transition in Agriculture.

- AcClimatize
    - Roadmap for the Agri-food sector developed by DAFM - to help all stakeholders reduce greenhouse gas (GHG) emissions, build resilience and adapt to the impacts of climate change. In order to contribute to achieving Ireland's goal of a climate neutral economy by 2050.
- Agriculture, Forestry and Seafood Climate Change Sectoral Adaptation Plan
    - Sectoral contribution to the National Adaptation Framework
- Food Vision 2030
    - Next 10 year strategy, following Food Systems approach for the first time
- Our Rural Future, 2021-2025
    - Government's Rural Development Policy, a multi-sectoral, national strategy

7. Circular agrifood systems in Ireland

OPPORTUNITIES, CHALLENGES AND ACTIONS NEEDED

Authors:

Helena McMahon | James Gaffey

Jennifer Attard | Tracey O'Connor

Eve Savage | Catriona Power

Carmen Giron-Dominguez | Aodhan Newsholme

Mary Anne Hurley

Credit: Shuttershock

Acknowledgements

MTU c would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Helena McMahon, James Gaffey, Jennifer Attard, Tracey O'Connor, Eve Savage, Catriona Power, Carmen Giron-Dominguez, Aodhan Newsholme, Mary Anne Hurley

Reviewers

Saskia Visser (EIT Climate KIC), Denyse Julien (EIT Climate KIC), Stewart Gee (EIT Climate KIC)

How to cite this Chapter:

MTU: Circular agrifood systems in Ireland: Opportunities, challenges and actions needed Chapter 7 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Circular agrifood systems in Ireland: Opportunities, challenges and actions needed.

Key to exacting effective change requires the investigation and integration of best practice in circular and bioeconomy related solutions and approaches from a European perspective and exploring how they can be implemented in the Irish context. Further acceleration in the just transition towards a zero-carbon society is needed across all sectors including the development of a systems thinking approach towards the creation of regenerative, circular and sustainable agrifood, land and marine opportunities.

This chapter offers an in-depth Irish focussed approach to circularity and the bioeconomy, providing an overview of the current landscape, recent developments and future sustainable pathways. Topic areas include the reduction of food waste across the value chain, innovation in sustainable biobased packaging solutions, circular business models for industry growth and the creation of connections between the quintuple helix of stakeholders; environment, civic society, government, industry and academia.

7.1 Food Waste Innovation

Food waste: an overview of what we know

Food, being a necessity, is at the core of sustaining human life but is a resource that is wasted at immense cost to society. The transition to a more sustainable future therefore cannot happen without a shift in the way food is produced and consumed. There are several definitions for what constitutes food waste. The European Commission (EC) defines food waste as food, and inedible parts of food, removed from the food supply chain, apart from:

- pre-harvest losses, i.e., losses that occur before the raw material is ready for harvest or slaughter
- mature crops that are ploughed back into the soil or left unharvested.

There are several approaches that can be taken to tackle food waste. The European Commission has developed a food waste hierarchy (Figure 7.1) that prioritises prevention of food waste as the primary solution, followed by re-use for human consumption, re-use for animal feed, revalorisation into value added products, nutrient recovery, energy recovery and lastly, disposal (European Commission Joint Research Centre, 2020). Ireland's Environmental Protection Agency (EPA) have adopted the same hierarchy. There is a strong business case for reducing food loss and waste: as evidenced in a recent 17-country study of business initiatives, almost all food waste prevention activities were found to deliver a net positive return (WRAP *et al.*, 2020).

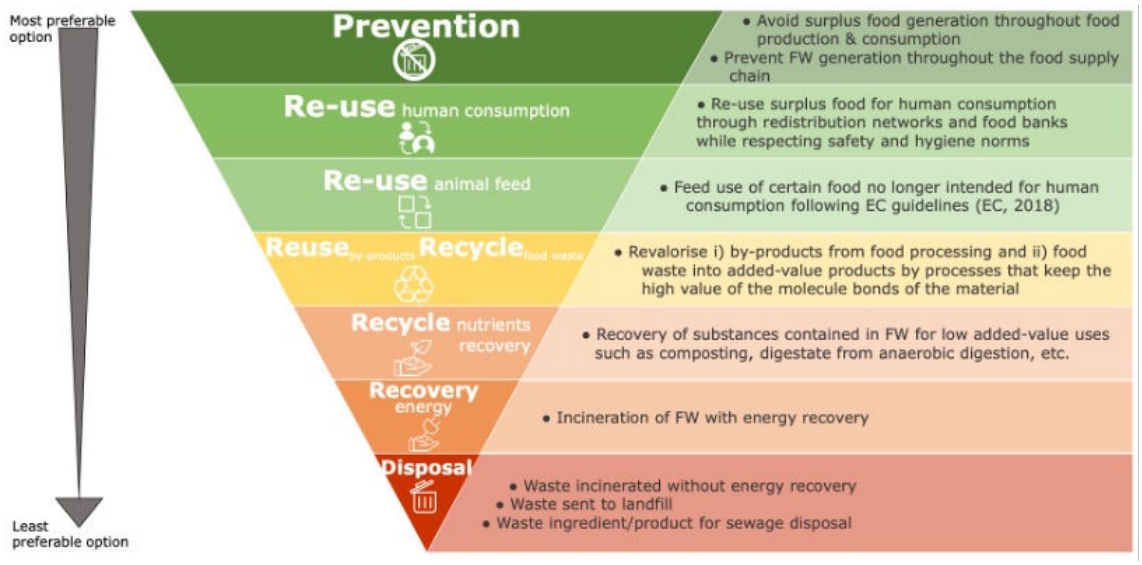


Figure 7.1 *Food waste hierarchy (EC-JRC, 2020).*

The EPA funded several studies to investigate measuring food waste locally in Ireland, along the supply chain, which is resulted in the following breakdown; primary production (9% of annual Irish food waste), manufacturing and processing (29%), distribution and retail (8%), restaurants and food service (23%), and households (31%) (EPA, 2022). This was in line with requirements by the EC to report on 2020 food waste quantities by June 2022 (EC, 2020).

Primary production was tackled by the Circular Bioeconomy Research Group at MTU Kerry, via the Efficient Food Project. The data gathered show that the annual food loss and waste (FLW) arising from primary production in Ireland amounts to 189,485 tonnes (70,400 tonnes of which is classified as waste) and the main problem area is the horticulture sector, in which FLW can average up to 40% in the case of some vegetables (Attard & O'Connor, 2022). A major issue was found in retailer contracts with producers, which contain strict specifications on price and quality, and can also include clauses allowing last-minute cancellations of orders. Another major issue is a lack of ecological and sustainable farming methods, which degrade the soil over time, creating weakened agricultural systems that constantly need to be artificially "repaired", for example by using synthetic fertilisers. Most producers interviewed as part of the Efficient Food Project study, deemed the resultant food loss as unavoidable, and believed improving their farming methods was economically impossible given the current price for food paid by processors and retailers in conventional supply chains (Attard & O'Connor, 2022).

The food and beverage manufacturing and processing sector in Ireland generated an estimated 239,400 tonnes of food waste in 2020. This includes foods that don't meet quality standards (size, cosmetic and aesthetic specifications, damaged products), foods unsuitable for consumption or processing (contaminated and unsafe products, product returns), process wastes (wastes arising during processing and cleaning) and inedible food (skins, seeds, bones etc.). Process wastes can arise from inefficient processing (excessive trimming, batch residues, improper packaging) or errors in processing from poor operational practices, instrumentation and controls (EPA, 2022; EC-JRC, 2020).

Commercial food waste encompasses distribution, retail, restaurants and any other food service. Food waste in these sectors adds up to 230,000 tonnes per year and occurs due to food damaged from a lack of cooling/storage facilities, poor demand forecasting and menu planning (including portion control), delivery issues (delays, oversized deliveries), too frequent replenishment of stocks (leading consumers to select most recent products), over-ordering by customer and a lack of communication both internally and with customers (EPA, 2017; EPA, 2022; Broderick & Gibson, 2019). The types of food being wasted the most in these sectors are fruits and vegetables (Broderick & Gibson, 2019).

Household food waste in Ireland amounted to 241,000 tonnes in 2020 (EPA, 2022). A survey conducted by Teagasc and NUIG as part of the Circular Agronomics project, investigated consumer behaviour in relation to wasting food in their household (McCarthy *et al.*, 2022). It was found that 32% of respondents waste food severely, i.e., cooking too much food, throwing away leftovers, throwing food away before cooking it. A similarly sized group, 29% of respondents, were less wasteful but were still likely to throw away fruit, vegetables and bread. The remaining 39% of respondents were the least wasteful, still cooking too much food but making sure to eat leftovers. The least wasteful group were more effective at meal planning, checking the fridge and making shopping lists, and were positively influenced by peer groups important to them who promoted food waste reduction (McCarthy *et al.*, 2022).

Tackling food waste

Ireland has taken steps to address food waste at a policy level with the National Food Waste Prevention Roadmap 2023-2025 (DECC, 2022). This strategy underlines the need for robust interim targets and measurement and reporting systems and calls for an updated strategy every three years. The 2023—2025 roadmap calls for interventions linked to priority waste types and audiences at household level. The capacity for waste prevention can be strengthened by expanding the targeting of interventions towards priority waste types and audiences at all stages of food supply chains, with initial focus on the most avoidable food waste (low—hanging fruits). The Food Waste Prevention Roadmap should also aim to highlight areas where food waste is most unavoidable, therefore highlighting where interventions that are lower-down on the Food Waste Hierarchy, e.g., innovations in food waste valorisation, should focus (Broderick & Gibson, 2019; EC-JRC, 2020).

As reasons for food waste along the supply chain can be interlinked, it is necessary to utilise a total value chain approach that increases collaboration and commitments along the chain. Local studies on food waste prevention have shown consistent recommendations for support on awareness raising, knowledge exchange and skills development (Broderick & Gibson, 2019; Attard & O'Connor, 2022; McCarthy *et al.,* 2022; O'Brien *et al.*, 2022). Apart from centralised training methods, shorter food supply chains can inherently improve knowledge for all actors due to the direct contact and communication. Transparency in production processes, and consumers' improved understanding of sustainable food production, could potentially increase the value of food as consumers may be willing to pay a premium for food that they trust. Collaboration between enterprises in food value chains can also support resource sharing between actors, particularly on a local level, who can share resources, e.g. mobile

processing facilities, community kitchens, on a need-driven basis to help prevent food waste that might otherwise occur due to distance from market/relevant processors, seasonal variability in processor and customer demand, and investment costs that prohibit enterprise investment on an individual basis (Attard & O'Connor, 2022; Broderick & Gibson, 2019). Collaboration across the value chain can facilitate food waste prevention at multiple nodes, e.g. improved communications between producers and retailers and retailer purchasing procedures, improved communication between hospitality and catering businesses and their customers, e.g. on portion size and canteen menu planning, and structural support among retailers to reduce household food waste, e.g. avoiding bulk buy offers on foods with short shelf-life, storage recommendations, and in-store shopping tips to prevent food waste (Attard & O'Connor, 2022; O'Brien ***et al.***, 2022; Broderick & Gibson, 2019).

Where food is edible but cannot be sold within the current system, there is a need for improved redistribution infrastructure, as well as small-scale food processing and better storage facilities, which would also benefit from resource sharing business models (Attard & O'Connor, 2022; O'Brien ***et al.***, 2022). However, such secondary solutions may not be economically feasible in the long-term if less food waste is in circulation due to successful food prevention strategies (Attard & O'Connor, 2022; Broderick & Gibson, 2019). FoodCloud, founded in Dublin in 2013, is an example of a leading national organisation which tackles food waste in Irish society, by distributing surplus food from retailers and producers to charities providing nutritious meals to people in need (FoodCloud, 2023). Thereby, offering an efficient service to companies, while simultaneously rescuing food and turning it into nutritious meals through the support of partner organisations, in turn reducing overall food waste in society.

Making good use of unavoidable food waste

Prevention of food waste is the most desirable solution. Nevertheless, a fraction of food waste will be unavoidable, e.g., spoiled food, and food waste will continue to occur while strategies to reduce food waste are being developed. For this reason, other approaches to food waste management are required, as described in the Food Waste Hierarchy (Fig. 7.1): re-use, recycling, and recovery (EC-JRC, 2020). When considering the utilisation of food waste, the aim is to ensure sustainable management of our natural resources. This means that priorities must be set to ensure food (and therefore also feed) applications first (re-use). Re-use of inedible food, e.g., fruit waste, as feed can help address the competition between food and feed and mitigate the resource use and carbon emissions associated with animal feed (Makkar, 2017). This aim can be supported by stimulating processor and manufacturer investment in product-driven food re-use as a priority, including as animal feed, with recycling (nutrient recovery and anaerobic digestion) as a secondary goal and energy recovery as the least-worst solution. Policy support for food re-use is necessary to ensure that food re-use as feed can be economically competitive with "virgin" equivalents, including imported commodities, e.g. supporting strategic partnerships between relevant stakeholders and localised food re-use networks (Klein, Neir & Tamásy, 2021).

Simple technologies that can be implemented at the scale of an enterprise or neighbourhood, e.g., densification technologies, can add value to food waste and crop residues while mitigating transport costs for these bulky materials. Biomass densification enterprises such as Südoststeirische Pelletierungsgenossenschaft, a four-person cooperative in Styria, Austria, which processes over 2,000 tonnes of biomass annually, demonstrate that this technology is viable at a local scale, enabling food waste to be re-used as easily managed, nutrient dense and storable pellets for feed purposes (COOPID, 2022a). Biogas production and nutrient recovery are twin outcomes of anaerobic digestion (AD) that provide opportunities to utilise food waste from which no further value can be recovered. These can also be implemented at varying scales from enterprise and neighbourhood level to regional level, and combined with other types of organic wastes, e.g., slurry, as demonstrated by Irish company Timoleague Agri Gen (2023). Biogas can be used to substitute fossil fuels, e.g., for machinery and vehicles, production facilities, etc., while nutrients recovered can be used as fertiliser and soil amendments, and these products can be sold to generate further income (Rajendran, Ó Gallachóir & Murphy, 2019).

A circular and cascading approach as applied in the use of biorefinery technology, can enable efficient processing of food waste for multiple purposes, including food and feed constituents, bio-active compounds, fertilisers and energy (through AD and energy recovery), generating greater value cumulatively than could be achieved through focusing on any single process, and maximising the use of food waste as a resource.

Figure 7.2. Carbery Group, Ballineen, Co. Cork

Irish dairy cooperative, Carbery Group, demonstrates how profitability can be supported by implementation of a minimum waste, circular and cascading approach to food processing, utilising 100% of the milk they receive through production of food, protein isolates, fertilizer and energy through methanol production and energy capture (see Fig. 7.3).

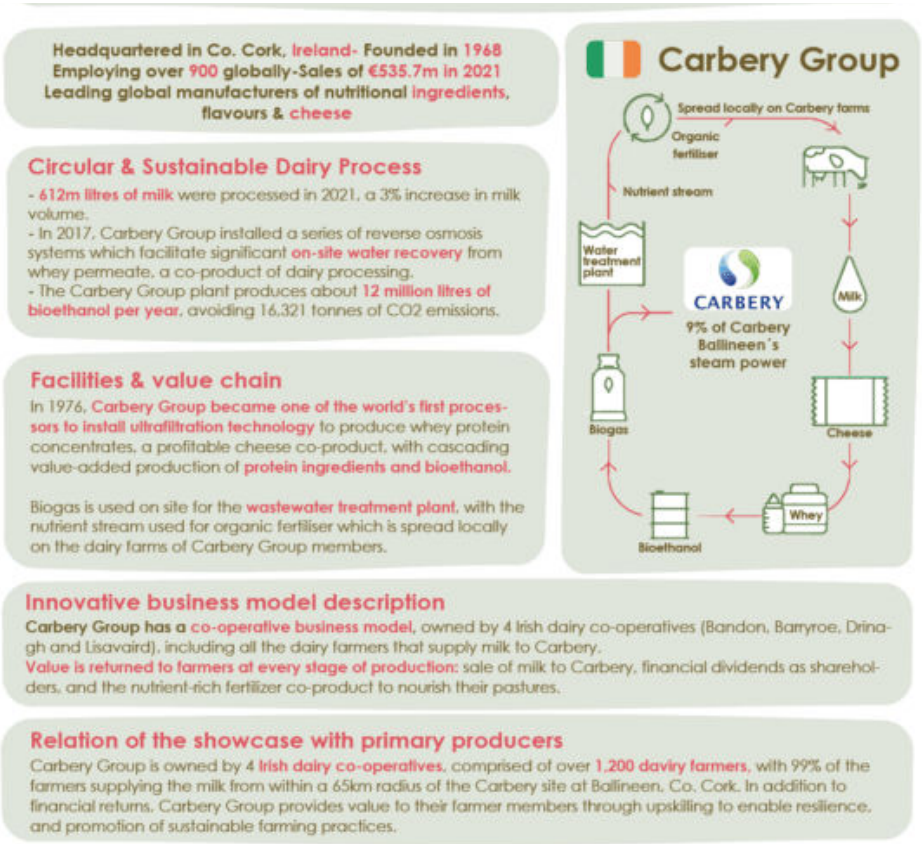


Figure 7.3. *Carbery Group's circular and cascading approach to profitable dairy production and processing (COOPID, 2022b).*

Food waste valorisation pathways

Food and feed ingredients, fibre, bio-active compounds and other food waste derivatives have multiple applications and can reduce demand for raw materials in industries such as healthcare and pharmaceuticals, furnishings and construction, and textiles. This approach is particularly effective if food waste can be segregated into different streams, as demonstrated in Fig. 7.4, and so is most applicable upstream in the food production, processing and retail stages of the food value chain. Fig. 7.4 shows a summary of valorisation pathways for food waste types along with the respective value-added products and applications, where the thickness of each line, represents the number of tested pathways in scientific literature (Caldeira et. al, 2020). High levels of valorisation can be observed with respect to some food groups in Ireland, e.g. the cascading use of dairy processing side streams as food ingredi-

ents, including concentrated whey protein that is used in infant, sports and medical nutrition (Carbery, 2023), neutralised whey permeate powder that is used for food production (Ornua Ingredients, 2018), and lactic acid and polylactic acid, whey permeate extracts that can be utilised in bio-based packaging production (AgriChemWhey, 2020) as well as the production of energy and nutrient-rich bio-based fertiliser side streams through the use of biorefinery systems for ingredient extraction (COOPID, 2022b; AgriChemWhey, 2020). In Irish primary production, the commercial sectors and in households, fruit and vegetables were the most wasted foods (Broderick & Gibson, 2019; Attard & O'Connor, 2022; McCarthy et al., 2022). This may indicate that food utilisation and valorisation innovations could focus on these food groups, to ensure a highly supply of inputs.

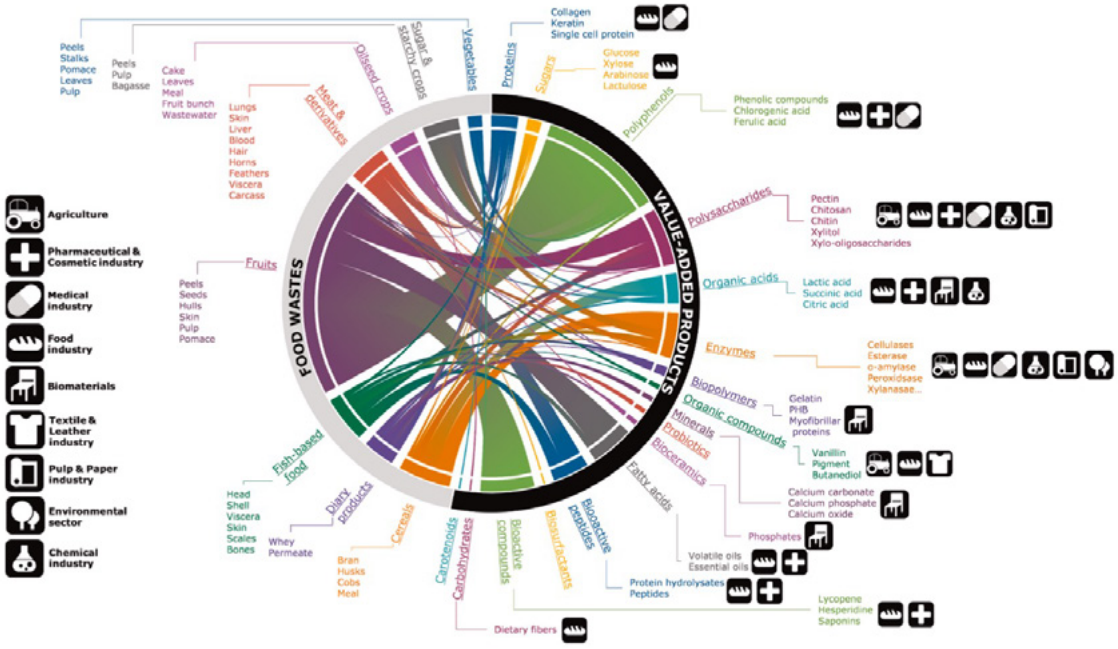


Figure 7.4: *Chord Diagram depicting the valorisation pathways of the food wastes, valued-added products, and applications (Caldeira et. al, 2020).*

Highlights

- Food waste is a major issue from a societal, environmental and moral perspective in Ireland, urgent cross-sectoral policy and industry action is needed to tackle this issue.
- Food waste occurs at various stages and the root causes vary between poor operations management in production to a lack of food related knowledge.
- Charities have stepped in to help save food and send it to charities in need, in turn providing an effective service for retailers, while also having positive environmental and social benefits in Irish society.

- Circular economy principles offer a potential solution to tackle food waste, by repurposing residues to new and changing thinking away from traditional linear based production systems to a more regenerative and self-sufficient system.

Recommendations

- Food waste is a muti-faceted issue, hence interdisciplinary and cross-sectoral collaboration is evidently required to develop more innovative and impactful solutions to effectively tackle the root causes of food waste in the long term.
- Knowledge sharing and awareness building could be improved to educate industry and citizens on the negative environmental and societal consequences of food waste.
- Producers and retailers play a fundamental role in tackling food waste issues, stricter regulatory measures could incentivize more effective solutions being developed to minimize food waste across the value chain.

7.2 Food Packaging Innovation

Given Ireland's strength as a food producing island, sustainable food packaging is a major area for potential innovation. The agri-food sector generates 7% of gross value added (€13.9 billion) and 9.8% of Ireland's merchandise exports (Teagasc, 2016). To remain competitive in this sector Irish producers, need to ensure that their produce is not only high in quality, but also leads the way on sustainability. In Ireland several companies are leading the way in integrating sustainable packaging while other initiatives are underway to develop new sustainable packaging materials. Examples will be discussed below.

Policy Context

The European Commission has set a target that all packaging on the EU market is reusable or recyclable in an economically viable way by 2030. To support this, the new Circular Economy Action Plan 2020 outlines the Commissions' commitment to reinforce the mandatory essential requirements for packaging including:

- reducing (over) packaging and packaging waste,
- driving design for re-use and recyclability of packaging, and
- considering reducing the complexity of packaging materials

The EU's plastics strategy adopted in 2018 aims to transform the way plastic products are designed, produced, used, and recycled in the EU. Several key initiatives have emerged from this strategy, most notably the Commissions directive banning specific categories of single-use plastics which came into effect from 2019. The Circular Economy Action Plan, also provides further commitments from the Commission to address the plastics challenge, including specific actions restricting and managing microplastics, and developing a policy framework on the sourcing, labelling and use of biobased plastics,

and the use of biodegradable and compostable plastics. It notes the plan to develop a strict labelling system for end-of-life use of such plastics which provides consumer with clear and accurate information.

In addition, the European Commission published a communication on biobased, biodegradable and compostable plastics after a stakeholder's consultation to ordinary citizens and professionals (Watson et al., 2022), to clarify whether these plastics can provide real environmental benefits and increase awareness. Special attention is given to the concept definition as well as suggesting and highlighting what is expected from industry and their use of bioplastics. They also state by the aspirational objective that at least 20% of the carbon used in chemical and plastic products should be from sustainable non-fossil resources to help reaching climate neutrality (European Commission, 2022).

In Ireland the Commissions ban on single use plastics was transposed into legislation in 2021, which specifically includes food packaging, containers, and cutlery, among other products. Further packaging measures are laid out in Ireland's Whole of Government Circular Economy Strategy 2022-2023 and Ireland's Climate Action Plan 2021, which aims to increase our capacity to recycle packaging waste by 70% and ensure all plastic packaging is reusable or recyclable by 2030. No specific targets are laid out for bioplastics, although a new Bioeconomy Action Plan is due to be implemented in 2023 which may include further information.

Understanding Bioplastics

According to the European Commission and European Bioplastics (European Bioplastics, 2015; European Commission, 2022), a plastic material is defined as a bioplastic if it is either biobased, biodegradable, or features both properties. Biobased means that the material or product is (partly or in full) derived from biomass (plants), while biodegradable means that microorganisms that are present in the environment can convert the material (e.g., plastic) into natural substances such as water, carbon dioxide, and compost. The Commission acknowledges a subset of biodegradable plastics which are the compostable plastics, typically composted through industrial composting in special facilities for composting or anaerobic digestion (European Commission Directorate-General for Environment, 2022).

Many biobased plastics, such bio-Polyethylene (Bio-PE) are "drop-in" plastics which directly replace an existing plastic, in this case fossil-based PE, and just as fossil-based PE is not biodegradable, neither is Bio-PE. Several other examples exist in this category including Bio-Polytrimethylene terephthalate (bio-PTT) and Bio-Polyethylene furanoate (bio-PEF). Then there is the category of biobased plastics which are also biodegradable. These include Polylactic acid (PLA), Polybutylene succinate (PBS), Polyhydroxyalkanaotaes (PHAs) and Thermoplastic starch (TPS). Finally, there are several fossil-based plastics which are also known to have the biodegradation properties, including Polybutylene adipate terephthalate (PBAT) and Polycaprolactone (PCL). An overview of the different types of bioplastics is presented in Figure 7.5.

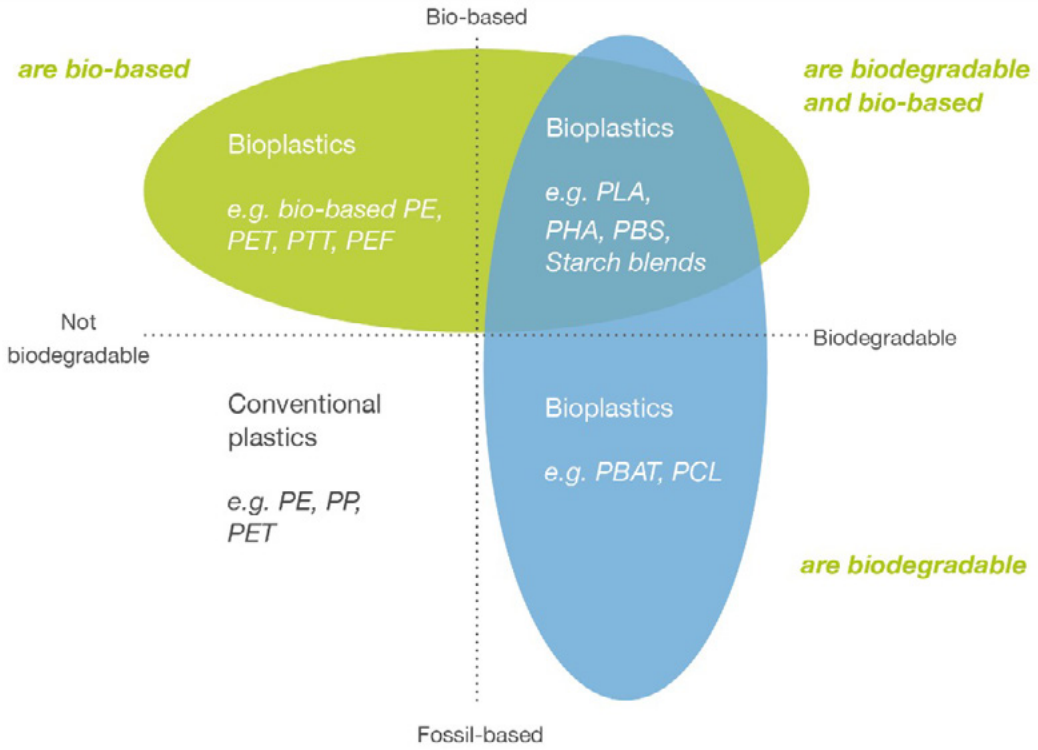


Figure 7.5: *Types of Bioplastics (European Bioplastics, 2015)*

Market for Biobased Packaging

Global production of bioplastic was 2.42 million tonnes in 2021 and is expected to increase to approximately 7.59 million tonnes in 2026 due to increased market demand, increase in supply of biobased alternatives and the removal of fossil-based plastics across many sectors of the economy. Currently, biodegradable plastics including PLA, PHA, starch blends and others, account for more than 64 percent (over 1.5 million tonnes) of the global bioplastics production capacities. Packaging was the largest market segment for bioplastics with 48 percent (1.15 million tonnes) of the total bioplastics market in 2021, with flexible packaging accounting for the majority followed by rigid (European Bioplastics, 2015). Surveys of both brands and consumers indicated that the upward trend towards bioplastic packaging along with recyclable packaging is likely to continue. A 2018 survey conducted by G&S Business Communications and Packaging World Magazine among 349 brand owners identified new packaging technologies (57%), biobased materials (38%), biodegradable packaging (38%) and increased recycled content (35%) as the main sustainability trends likely to drive change in packaging processes over the next 5 years (Gaffey, McMahon, Marsh, & Vos, 2021). A 2020 study of brands undertaken across Europe, indicated that 95% of brands, who don't currently use biobased packaging, expect to use some biobased packaging within the next 5 years (Gaffey, McMahon, Marsh, & Vos, 2021). Consumers in

Ireland, meanwhile, have indicated positive attitudes to biobased packaging. Among 500 consumers surveyed, 86% indicated that are likely to purchase more biobased packaging products in the next 5 years (Gaffey, McMahon, Marsh, Vehmas, et al., 2021).

The EPA Plastics Report 2022 key findings on attitudes and behavior in Ireland states that nearly 9 in 10 of respondents (86%) are aware their personal actions can reduce plastic waste in the environment. 81% are willing to take steps to reduce their plastic waste even if it impacts convenience and costs them. 85% said they have encountered barriers to reducing plastic waste. Access to alternatives (51%) and perceived high costs of buying products with sustainable packaging (45%) were the primary barriers reported. Over half of the population (56%) believe that they produce most of their plastic waste at home, with plastic food packaging from supermarkets considered to be the main sources (56%). Two in five (41%) state that they always 'search package information for what bin to use for their plastic packaging'.

Early Adopters

Several early adopters of biobased packaging exist within the food and beverage sector. In 2019, the Danish-Swedish dairy multinational Arla Foods announced that they were making 600 million fresh milk cartons renewable across their main EU markets, with the inclusion of bioplastic derived from sugarcane or forest waste (Arla Foods, 2019). It is estimated that these cartons will contribute 25% less carbon dioxide into the atmosphere compared to their fossil-based plastic predecessors. From 2005 to 2019, Arla has reduced the CO^2 impact of its packaging by 25%, equating to 123,000 tonnes of CO^2 being diverted from the atmosphere. In the drinks sector several global brands including Pepsi and Coca-Cola have been competing to develop a fully biobased or "plant" bottle (Gaffey, McMahon, Marsh, Vehmas, et al., 2021). The New Plastics Economy Initiative launched by Ellen McArthur Foundation in 2018 now includes over 500 brands among its signatories, including many prominent food brands and brand owners, such as Nestlé, Diageo and Mars. The companies which have signed up have agreed to make 100% of their plastic packaging reusable, recyclable or compostable by 2025. In Ireland, several (Gaffey, McMahon, Marsh, Vehmas, et al., 2021) early adopters have also been joining the trend.

Figure. 7.6. *Sample of Lee Strand Tetra Rex packaging solution*

In 2019, Kerry Dairy company Lee Strand launched the Tetra Rex plant-based carton into the marketplace, a fully renewable milk container (Fig.7.6). The pack includes a mixture of drop-in bioplastic Bio-PE and wood fibre. Lee Strand have invested over €2 million in manufacturing technology to offer customers this sustainable option and have increased their renewable packaging from 4% in 2019 to 23% in 2020 (Lee Strand, 2020). This transition has helped the company to increase its sustainability credentials and has opened the door to new business opportunities and clients. Other major Irish brands such as Lyons Tea and Bewleys Coffee are among some of the other household food brands that are leading

a shift towards biobased ingredients and packaging. Both have a particular focus on compostable plastics. A 2020 survey of brands found that the main motivation for brands choosing biobased materials was meeting their company sustainability targets, their customers' expectations, and creating new opportunities from greening their credentials (Gaffey, McMahon, Marsh, Vehmas, et al., 2021).

In addition to sustainable biobased plastics, other companies are looking at inclusion of recyclable plastics, or a mixture of both. Unilever have recently made a pledge to ensure that 100% of their plastic packaging is designed to be fully reusable, recyclable, or compostable by 2025. Kellogg's have made a similar 2025 commitment.

Innovation in Sustainable & Biobased Packaging

Ideally, producers should first consider how they can safely avoid and reduce packaging in the first instance (Reike et al., 2018), which can often be witnessed at local farmers markets across Ireland. If packaging is unavoidable more innovation is needed in the industry to increase sustainable outcomes across the value chain, which will be explored below.

One of the challenges that exist for companies is the perceived expense and cost involved in transitioning to sustainable packaging sources such as biobased packaging. This was highlighted in 2020 survey which noted high cost as the top barrier for brands and companies switching to biobased materials (Gaffey, McMahon, Marsh, Vehmas, et al., 2021). However, as noted by the BIOSWITCH project, switching to biobased may also help a company achieving its Corporate Societal Responsibility (CSR) targets, and/or give it a "green" profile, thus making it more interesting to work at, invest in, lend to, or buy from (Project, 2021). In addition, there are several innovations in the food packaging sector which may offer unique benefits to companies depending on their requirements. Notable innovations in food and beverage packaging include:

- PolyEthylene 2,5-Furandicarboxylate (PEF) – PEF is a biobased alternative to fossil-based PET commonly used in plastic packaging, including plastic bottles. Aside from being biobased, PEF offers functional benefits to PET including improved CO^2, O_2, and water properties. This can help to increase the shelf life of food (Avatium, 2020).
- Polylactic acid (PLA) - PLA is compostable and can offer benefits in the development of a variety of food packaging applications. For example, tea bags which often contain fossil-based plastics such as polypropylene are known to break down to release microplastics during the brewing process. PLA has been integrated recently by notable tea brands such as Lipton and Lyons tea to overcome this challenge and produce fully biobased and compostable tea bags (Lyons, n.d.).
- Home composting bioplastics – Many plastics which are compostable are only compostable within industrial composting facilities, which can create a logistical issue for consumers. This means the packaging often requires elevated temperatures, additives, and long times to break down. Work has been ongoing to develop bioplastics which are compostable within a home setting, making it much easier to ensure appropriate end of life management (Barret, 2018). These packaging materials are often the result of bioplastic blends, consisting of a mix of biodegradable fossil-based

plastics and biodegradable biobased plastics (Barret, 2018). Recent work from Irish researchers highlights the role that Irish companies can play in supporting this innovation. While Aldi and other brands have already begun to integrate this packaging option within their food and vegetable products (Origin Green, 2021).

In addition to innovation opportunities in packaging use, there is also a major opportunity for Irish companies to become producers of sustainable packaging. In relation to biobased packaging materials, several global leaders dominate the market in bioplastic production including Braskem in Brazil (Bio-PE production), Natureworks in USA (PLA production), Corbion in Netherlands (PLA production) and Novamont in Italy (Thermoplastic starch). Most of the bioplastic currently on the market is derived from first generation feedstocks such as sugar beet, sugarcane, and maize. At the research and demonstration level, several companies and projects are exploring the use of second-generation feedstocks, such as crop wastes or processing side streams to produce biobased packaging. This has the benefit of using a lower cost feedstock, while the overall footprint is also generally lower. Examples of initiatives developing food packaging materials from secondary feedstocks include AgriMax (food and fruit waste), BioSupPack (Brewers Spent Grains) and RefuCoat (agricultural side streams). UK based Notpla have developed a plastic alternative called "Notpla" made from seaweed. Its products include a coating for takeaway boxes, film, paper made from seaweed pulp, and a rigid plastic alternative, also made from seaweed. In 2021/22 they produced over a million takeaway food boxes for the JustEat takeaway delivery platform.

For Irish companies, there are many opportunities to become developers or suppliers of biobased packaging and some Irish companies are already leading the way in this regard. Tirlán (Glanbia) are one such example as leaders of the Circular Biobased Europe Joint Undertaking AgriChemWhey Flagship biorefinery project which aims to convert cheese processing residues, delactosed whey and whey permeate into high purity lactic acid for use in PLA production (Biobased Industries Joint Undertaking, 2020). Aiming to deliver innovation and increased sustainability along the fresh food supply chain, SFI's Leaf No Waste project targets both the production and packaging phase of food (Technological University Dublin, 2021). The project takes a novel approach in combining innovative plant stimulants and compostable packaging solutions to optimise the shelf life of fresh produce and minimise food spoilage and waste along the supply chain. Given Ireland's abundance of natural resources across agriculture, forestry and the marine sectors, the development of a biobased packaging sector based on these resources holds significant potential within a global bioplastics market which is growing at 7% per annum, driven largely by the increased demand for sustainable packaging. Other innovations focus on integrated ICT solutions. Initiatives such as REAMIT and Freshbox aim to use solutions such as sensors, Internet of Things and Big Data technologies to increase the sustainability of food across the supply chain, including the development of smart packaging solutions. On the supply side Down2Earth materials (fig. 7.7) are one of the leading suppliers of sustainable food packaging in Ireland and working alongside Vegware offer a broad range of compostable and sustainable food packaging options (Lyons, n.d.). The company works with over 400 food business across Ireland.

Figure. 7.7: *Sample of down2earth packaging solutions*

Highlights

- Due to the changing regulatory framework surrounding plastic packaging, and in particular single use plastics, Irish companies face the challenge of transitioning to more sustainable alternatives.
- While challenging, this transition also represents a business opportunity for Irish companies, and this can be seen both on the production side (e.g., Glanbia) and use side (e.g., Lyons tea).
- Survey results demonstrate that brands (95%) as well as Irish consumers (86%) overwhelmingly expect to purchase more biobased packaging products over the coming years. This along with current market projections, indicate a strong market trend for biobased packaging.
- Apart from offering greater sustainability, biobased packaging and other innovative packaging solutions often provide certain addition functional benefits which make them more attractive.
- There is a harmonized EN standard for industrially compostable packaging, and for one biodegradable in soil mulch firms, used in agriculture. There is no general standard for marine biodegradation.

Recommendations

- Firstly, examine how you can avoid and reduce packaging for optimal sustainability performance, then explore innovations to simplify packaging for improved end-of-life management.
- There are now several Irish early adopters of sustainable packaging. Highlighting these industry champions can provide inspiration for other companies to follow.
- Many companies need support in transitioning to sustainable packaging materials and supporting eco-systems to allow them to identify the correct solution and connections with solution providers is required.

- As some of these packaging solutions are new, retailers, companies and consumers require more support in understanding the end-of-life terminology and in understanding how to manage these appropriately. Clear labelling and information are key, while additional waste management infrastructure will also be required.
- To fight greenwashing and avoid misleading consumers, generic claims on plastic products such as 'bioplastics' and 'biobased' should not be made.
- Support will also be required for innovative Irish companies (and universities) aiming to produce sustainable packaging materials, but this activity can contribute to Ireland's 2050 Climate Neutrality Targets, assist in the transition to a circular economy, along with reducing our material import dependence.

7.3 Circular Business Models for the Bioeconomy

A Sustainable and Circular Bioeconomy has been identified and prioritized by governments and policy-makers as one of the key means by which to enable the transition to a net zero carbon economy and positively contribute to the mitigation of climate change addressing issues such as land and ecosystem degradation, the growing demand for food, feed and energy, the utilization of finite resources and the need for new models of production and consumption.

First articulated as the 'Knowledge Based Bioeconomy' (KBBE) by the seminal work of Christian Patermann in 2005, there have been several definitions of the bioeconomy all of which emphasize the sustainable production and use of natural resources, clean technologies, new and alternative biobased product development and the mass transition away from fossil resources.

The emergence of the Circular Economy and related concepts provided an additional framing and set of requirements for progression to a Sustainable Circular Bioeconomy such as a reduction on the dependency on the use of new resources (biological and technical), zero waste and cascading principles, industrial symbiosis, product and material use, resource life extension eco-design and eco-efficiency, supply chain innovation, regeneration and closed loop production.

A key strength of the Circular Bioeconomy is it scope and scale, for the regeneration and utilization of renewable biological resources (biomass and side streams) from forestry, marine and agriculture to produce biobased products for food, feed, agronomy, cosmetics and personal care, textiles, construction, pharmaceutical and energy uses (Gatto & Re, 2021). This has resulted in the development of wide-ranging technologies from cascading zero waste biorefineries to gene editing, monitoring and conversion technologies and platforms.

The upscaling of the circular bioeconomy can only be achieved via large scale uptake of this model of sustainable economic growth encompassing Start-ups and Scale-up's to established SMEs and Multi-national. The number of companies involved in circular bioeconomy in Ireland is increasing year on year. A national study was carried out in 2020 and 2022 by Kieran Harrahill and Professor Aine Macken-Walsh of Teagasc mapping the bioeconomy network nationally. This study of the multi-actors revealed a significant increase in the number of companies actively engaging in the bioeconomy with companies from SME to MNC across sectors in agri-food, marine, waste management, agri-technology, renewable energy, packaging, software solutions for carbon management, pharmaceuticals, consultancy, 3-D printing among others. A recent study by the Irish Bioeconomy Foundation and Intertrade Ireland estimated that there are approximately 600 companies involved in advancing bioeconomy related products and services.

Industry mobilization is evident in Ireland with multi-sectoral involvement at all scales, start-ups (BiaSol, Pure Ocean Algae, Real Leaf Farms), scale ups (Hexafly, Biomarine Ingredients, Verifact, Samco), large companies (Gas Networks Ireland, Carbery) and multi-national companies (Kerry, Glanbia, AllTech) testing or transitioning to bioeconomy opportunities. This is hugely encouraging however the number of companies engaging and investing in bioeconomy development is low given the dominance of the agri-food, forestry and marine sectors in Ireland with circa 10 million farms in Europe, 15,000 fisheries and aquaculture enterprises and > 500,000 employed in the forestry sector.

To date the focus has been on technological innovations as a key driver and enabler of bioeconomy growth, this alone is insufficient, there needs to be an increased focus on commercialization pathways, economic feasibility, business model design and investment, (Reim et al. 2019).

Whilst the knowledge on the development of bioeconomy products and processes has progressed at pace there is a limited knowledge base on Circular Bioeconomy Business Models. This lag is due to the convergence of longer innovation cycles and the diversity in bioeconomy value chain partnerships, technologies and product which increases the time to market and prevents large scale business model replication as is possible in other sectors e.g., SaaS, software as a service. This is compounded by the high levels of variety in bioeconomy value chains which are rarely based upon a single innovation in going from biomass to consumer, be that in a B2B, B2C or D2C context. The diversity in value chains (inputs, processing, products and services), route to market (sectors and sub-sectors), innovation & industrial models, fragmented regulatory, policy and funding landscapes, translates to complex and challenging commercialization pathways and business model design requirements.

Given that companies advancing on bioeconomy opportunities will be at different scales and status (e.g., Start up v SME) there will be a variety of unique conditions and shared requirements in terms of business model innovation reflective of the business stage. In the case of the SME or large company that is diversifying (transitioning operations), they will need to develop a business model that can successfully commercialize the new technology, product or service in question, whilst co-existing and ideally creating or leveraging a synergy with pre-existing business activities, without placing financial or operational pressures.

In contrast the start up or scale up may have more freedom to operate but will not have the foundational pillars that an established business can bring in terms of networks, supply chain partnerships, access to capital and or customers. The Circular Bioeconomy Business model requires a new skill set taking systems innovation approach. A circular bioeconomy business model is one that aims to establish a system that is naturally regenerative, eliminates the use of virgin and fossil derived input, maintaining maximum resource value for as long as possible, through designing out waste, resource cascading and loops, to create new technologies, biobased products and services replacing and eliminating the need for finite resource-based products and services. The core principles of business and business model development still apply and remain foundational, the 9 pillars of the business model canvas as proposed by Osterwalder and Pigneur in 2010 still apply and continue to be central to the design of any circular bioeconomy business model, these are: 1) partners, 2) value proposition, 3) key activities, 4) key resources, 5) customer relationships, 6) channels, 7) customer segments, 8) costs and 9) revenue streams.

Taking the business model canvas, expanding and adapting to integrate key sustainability focused elements such as natural, technical, energy and water resources, waste management (next use /end of life), environment impact (positive / negative), societal impact (positive / negative) is the principal way in which business model innovation has been framed and codified. With the mass adoption of the business model canvas this approach provides a framework that can be readily understood and deployed and adapted.

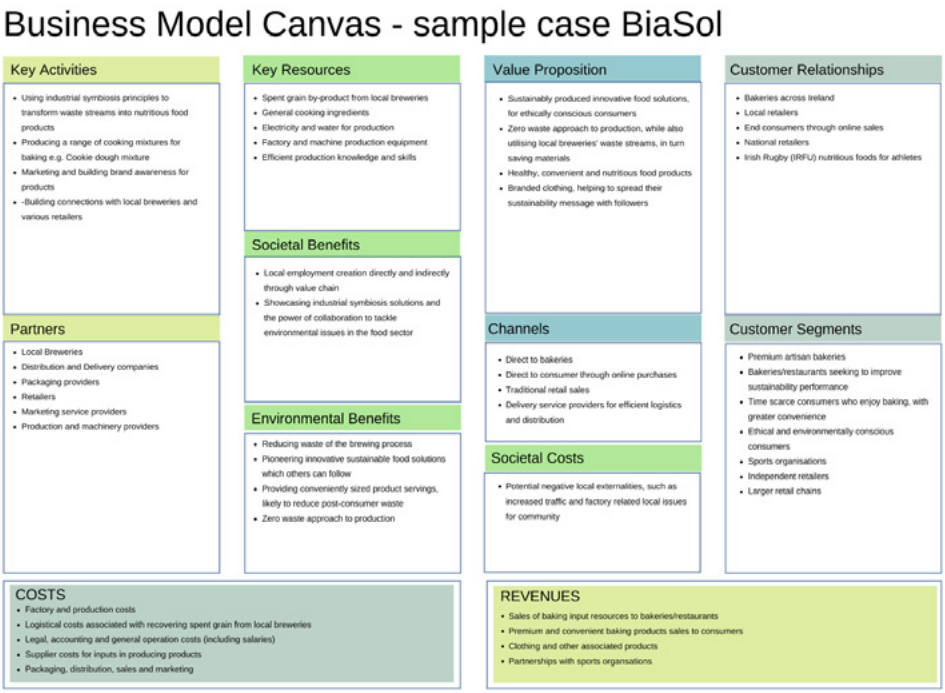


Figure. 7.8 : *Adapted Business Model Canvas: BiaSol a family-run company in the heart of Ireland creating a range of innovative food solutions through the valorisation of side streams from the brewing industry.*

The additionality and differentiation of a circular bioeconomy business model is inclusion of natural capital utilisation, regeneration, supply chain innovation, zero waste, product life extension, end of life parameters and social impact at the core of the business model. Several tools such as the *Circulab Circular Canvas* (Fig. 7.9) and the *Ecocanvas* are available to support companies in the design and development of their business models which include additional circular business model criteria which are relevant and can be adapted to circular bioeconomy requirements[145].

Figure. 7.9. *Circulab Business Model Canvas template*

However, given the diversity of the circular bioeconomy – which is bringing together bioeconomy and circular economy, adaptation is needed and where experienced professionals with circular bioeconomy and the relevant business knowledge and expertise are required to support, and sense check the business model development activities. To date the first to market and most disruptive circular bioeconomy companies have led the way in business model and organizational development, very much setting the standard and benchmark for the sector with key examples highlighted in the next sections.

145 https://circulab.com/toolbox-circular-economy/circular-canvas-regenerative-business-models/

Circular Bioeconomy Business Models – Case Studies

Dairy sector to building blocks for bioplastics

photo credit: Shutterstock

AgriChemWhey[146] is a major industrial venture (Flagship Biorefinery) led by Glanbia, designed to convert residues from food processing in a bid to enhance the circular bioeconomy through agriculture and agri-food waste. Whey Permeate (WP) and De-lactosed Whey Permeate (DLP) are major by-products of dairy processing representing a significant challenge for the dairy industry due to current unreliable disposal routes creating a sustainability bottleneck for the expansion of milk production across Europe in the "post-milk-quota era". AgriChemWhey is seeking to build a first-of-a kind, industrial-scale biorefinery with integrated symbiotic industrial and agricultural value chains that will have capacity to valorise over 25,000 tonnes (100% dry matter) per annum of excess WP and DLP to several added value products for growing global markets including lactic acid, polylactic acid, minerals for human nutrition and bio-based fertilisers. Representing the first major industrial venture of this scope through a coordinated investment process and development path, to create value added bio-based products converted from food processing residues.

146 https://www.agrichemwhey.com/

The transformative power of potato production

Figure. 7.10. *Meade Farm Ltd potato starch product cooking alternative for corn flour*

A staple food in Ireland, the potato industry has diversified in recent years offering complementary products and adopting circular business model to grow business in the sector.

Meade Farm Ltd[147] in County Meath has developed a multi-prong approach to sustainability, from sourcing organic inputs to factory energy efficiency and managing waste streams effectively. The farm follows a zero-waste approach, using the full crop, partnering with social enterprises and using potato peels in the production of alternative products, in turn simultaneously offering a new revenue stream while repurposing residues which may have otherwise ended up as a waste. One of their complementary product innovations is the development is a potato starch (fig. 7.10) which is used as a cooking alternative for corn flour and traditionally must be imported into Ireland, in turn reducing environmental emissions in distribution and reducing waste in their factory.

Another innovative business in the Irish potato industry is Keogh's[148] located in county Dublin. Keogh's offer a wide range of potato products and have diversified into producing premium quality crisps, again proving new revenue streams while using more of the crop. They have been certified as a carbon neutral business and have recently partnered with an Irish based development agency 'Vita' to share their knowledge of effective potato growing best practices to help empower farmers in Southern Ethiopia to become more sustainable and self-sufficient.

These examples offer insights into reducing waste, diversifying product portfolio to higher value offering, increasing efficiency in operations both within their production system and across their value chain from initial sourcing to disposal in order to better facilitate circular collaborations with stakeholders.

147 https://www.meadefarm.ie/
148 https://www.keoghs.ie/

Alternative Protein Production

Figure. 7.11: *Hexafly Ltd alternative protein produced by the farming of black soldier flies*

Insects offer a sustainable protein source; they are also a good source of vitamins and minerals whilst simultaneously being environmentally friendly. Insects need significantly less resources such as land and water, and their waste can be repurposed and used on farms as fertilizer. Hence insect farming has become a potential area for farm diversification offering a sustainable source of protein for environmentally and health-conscious consumers. *Hexafly Ltd*[149] headquartered in County Meath, aim to revoloutionise insect farming and find smarter ways to feed the planet. They were established in 2016 and have secured significant funding for further expansion in the coming years. They have expertise in farming black soldier flies, which they claim have the potential of 'feeding the planet'. Currently they produce insects for animal consumption in an environmentally efficient and nutritious way, when compared to traditional methods. Internationally, companies such as the French company Ynsect have grown rapidly by using insects as a nutritious and sustainable source of protein in the human diet, illustrating the consumer demand and potential development opportunities for further growth in this sector, resulting in less resource intensive forms of food production.

149 https://hexafly.com/

Developments in the Dairy sector paving a sustainable path for agrifood systems

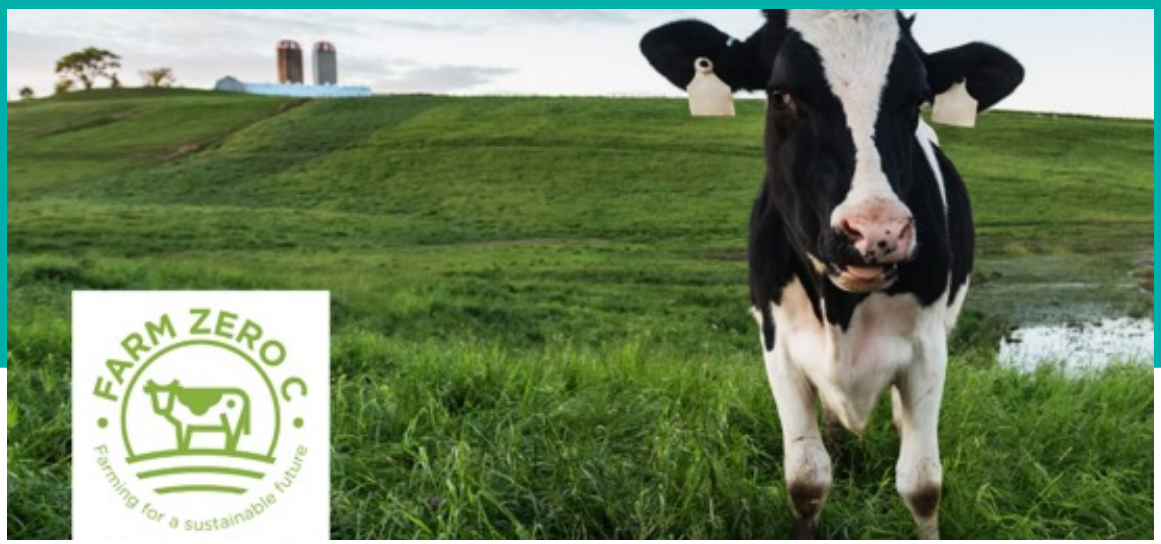


Figure. 7.12: *FarmZeroC project wins Science Foundation Ireland zero emissions challenge*

Glenilen farm[150] in county Cork has embraced a more circular approach to dairy production, from inputs to the management of packaging in the post-consumer phase, for example their yoghurt pots can be effectively upcycled to extend their life and used for other convenient purposes, such as storage. Glenilen source milk inputs on their own and neighboring farms in the locality which reduces waste, this proximity offers fresh and energy efficient opportunities for their dairy production. They have also taken several on-site measures, such as rainwater harvesting and installing solar panels to reduce costs and improve overall environmental performance in their production system. Along with other biodiversity enhancements such as tree, hedgerow and wildflower planting to improve habitats for local flora and fauna, Glenilen is showing positive steps in their journey to becoming a more sustainable organisation and sets an example for others to follow in terms of improving circular economy performance throughout the value chain.

Carbery[151] a co-operative dairy farm in county Cork, which has been discussed above, recently set ambitions to become net zero and has recently won the Science Foundation Ireland zero emissions challenge with their Farm Zero C project (fig. 7.12). This project securing 3 million euro providing the resources to explore innovative and circular solutions and is likely to uncover replicable insights for similar farms on their climate neutral journey, by highlighting barriers and opportunities for transitioning to more sustainable farms. Carbery is also actively involved in the Biorefinery Glas project is which aims to demonstrate small-scale biorefinery in Ireland and develop new circular business models for farmer diversification into the bioeconomy.

150 https://glenilenfarm.com/
151 https://www.carbery.com/

Industrial Symbiosis growth potential, Bread to Beer pilot study

Figure. 7.13: *Industrial Symbiosis innovation demonstration pilot between St Mel's Brewery and Panelto Food funded by the EPA's 2019 Green Enterprise Fund.*

SymbioBeer [152] a recent industrial symbiosis feasibility initiative, funded by the Environmental Protection Agency's Green Enterprise Programme in 2019 between two proximal Longford based business offers an insight into the potential similar learnings and collaborative partnerships across the wider agricultural sector. Industrial symbiosis involves turning the wastes or by products of one industry into the raw materials for another, allowing for resources to be used in a more sustainable manner and reducing overall waste in production systems. Industrial symbiosis offers lucrative benefits, including improved resource efficiency, reduced costs and more resilient supply chains, although it requires the establishment of a trusting and collaborative partnership between organisations, which is often difficult to achieve. Bread waste is utilised as a substitute for virgin malted grain to create beer, in turn a new bread is produced using outputs from the beer production, in turn closing the loops of production at a local level. This is an ongoing collaboration between Panelto Foods and St Mel's brewery facilitated by 'Irish Manufacturing Research' and highlights the promising potential of turning waste-streams into inputs in another production processes, in this case from bread to beer production. Similar success stories in side stream valorisation in other locations such as Toast Ale in the UK.

152 https://imr.ie/pages/symbiobeer/

Challenges for companies and SMEs

Existing

The development and commercialization costs associated with bringing a biobased product to market will often be borne by the company finances. Attracting external funding can be difficult due to the time span between when capital investment is made, and the potential resulting sales and profits materialise. The management team plays a crucial role in the commercialisation process taking the product to the market. Companies may require additional contracted management and team members to engage specialist expertise from outside the company and to collaborate with professional investors or via joint ownership models (European Commision, 2019). There is often an imperative to partner with another organisation to alleviate supply chain challenges including access to feedstock and other inputs, to increase production capacity; and opening market access routes. Having appropriate Patents and IP already in place are important conditions to attracting and mobilization of finance. This investment may be possible in larger consolidated companies, however in smaller companies it is typically the owner(s) and founders that must demonstrate their willingness to invest time and money and expertise in the development through accessing finance from private loans or savings.

Barriers affecting business innovation

The upwardly rising trend in industrial research studies focusing on circular bio-based models suggests a rapid shifting toward a circular approach with small and medium-sized enterprises (SMEs) and start-ups playing a key role. Several factors influence the success or failure of bio-based products over fossil-based products (Jernström et al, 2017). These include high production costs, consumer awareness of the related benefits and low investor confidence in high-risk untested business models Although more and more consumers recognise and are interested in circular, sustainable and biobased products and services, SMEs and start-ups often adopt non-innovative 'tried and tested' solid business models to gain and build trust with potential investors, financial institutions and to participate in existing marketplaces which are inherently structurally linear.

Creating circular business models is rising on the agenda for sustainability focused business-led coalitions and stakeholder groups requiring a radical rethink and reshaping of linear business models and processes. Creating financially viable circular bioeconomy business models require the presence of an integrated supply chain armed with the financial, regulatory and production knowledge to leverage public subsidies that stimulate the creation of joint ventures between logistic brand owners and primary producers.

Support required

Transitioning towards a zero-carbon economy requires large scale actions coordinated across all parts of society and the establishment of a variety of enabling mechanisms that can be activated across European, national and local government levels. Circular bioeconomy products and services are predicted to reach a value of 8 trillion Dollars by 2030. For Ireland to reach its potential, there needs to be a suite of expert led circular bioeconomy business intelligence, supports and finance available to de-risk and maximise the chances of success. A strong awareness and insights into the challenges that may arise with strategies for early identification and mitigation is essential. Broring et al. (2022) identified 8 challenges to bioeconomy business model development, which are categorized as technological, market, value chain / ecosystem, geography, economic viability, regulatory and organizational challenges. Other challenges identified in the literature include volatility in natural resource (biomass and side-streams) pricing, identifying customer segments & customer behavior, logistics costs in circular businesses, absorptive capacities (skills and talent) and investment.

The updated EU Bioeconomy Strategy 2018 sets out three main action areas one of which includes strengthen and scale up the biobased sectors & unlock investments and markets; which is very much aligned with investment in and prioritization around well supported and effective circular bioeconomy business model development and may provide a channel for leveraging of EU investment in this area.

Given the potential of the sector to create companies with potential for scaling internationally support agencies such as Enterprise Ireland can provide key supports across the following areas:

- Accelerator programs - start up v transitioning
- Business model mentor programs
- Funding for business case development
- Funding for scaling
- Facilitation role for circular collaboration across industries and value chains
- Further pilot studies on industrial symbiosis potential in the agrifood sector

Connections and Opportunities

Green transformation presents new market opportunities and enterprise developments for Irish based companies. This transformation refers to the design and deployment of processes within sectors, industries or companies that lead to reduced environmental change impact (Climate Action Plan, 2021).

As a small country, it is necessary for Ireland to target strategic investment in specific areas of enterprise research and innovation (Dept of Enterprise, Trade & Employment, 2022). Several Research Prioritisation Areas (RPA) were identified valid from 2018 to 2023 comprising:

- Health and Wellbeing, including Medical Devices, Connected Health and Independent Living, Therapeutics and Diagnostics;
- Energy, Climate Action and Sustainability including Decarbonising the Energy System and Sustainable living;
- Food including Food for Health and Smart and Sustainable Food Production and Processing;
- ICT including Future Networks, Communications, Internet of Things, Data Analytics, Artificial Intelligence, Digital Platforms, Content and Applications, and Augmented Reality and Virtual Reality;
- Manufacturing and Materials, including Advanced and Smart Manufacturing, Manufacturing and Novel Materials; Innovation in Services and Business Processes.

This prioritization by the government provides the opportunity for new and emerging business opportunities and the creation of new value chains to develop both from within and beyond the agrifood sector. The defossilisation of major economic sectors, including the agriculture and food sector, the chemical industry and the wooden construction sector, offers possibilities for both long-term carbon sequestration and the implementation of the low carbon economy.

Cluster networks as collaboration drivers

The importance of cluster networks is recognised by the government in the development of a new National Clustering policy framework through the identification of regional and national sectoral strengths. This will encourage the formation and strengthening of existing national cluster organisations and maximise the scale, impact and international visibility of Irish clusters, (Dept Enterprise Trade & employment, 2022). A cluster unlocks and accelerates business opportunities and new value chains across sectors. An active cluster with industry, SMEs, educational institutes, government and finance stakeholders working together towards similar goals through targeted programmes will speed up the innovation cycle, foster talent and support both regional and national enterprise growth. Connectivity with, and engagement between, enterprise and regionally based knowledge providers, such as the IoTs / TUs, drives productivity and competitiveness in and across regions. Cluster networks can help accelerate innovation in regional areas. The Cluster Centre is the

all-island network for clusters, cluster initiatives and policy makers. There are several Enterprise Ireland Agri-food related and adjacent cluster networks funded by the Regional Technology Cluster Fund including the Agritech Ireland Cluster, Circular Bioeconomy Southwest, Wood Connect and the Killibegs Marine Cluster.

Figure. 7.14: *Circular Bioeconomy Cluster Southwest at Munster Technological University, Kerry*

The Circular Bioeconomy Cluster South-west (fig. 7.14) is an industry network funded by Enterprise Ireland, the government agency responsible for supporting Irish businesses in the manufacturing and internationally traded services. With a focus on marine, agriculture and waste-to-value thematic areas, the cluster brings together industry, enterprises, government and research centres to deliver unique and co-created initiatives to benefit its expanding company membership which span the island of Ireland. This accelerates R&D opportunities through partnering services, accelerator programmes, investor funding and new market connections. The cluster facilitates knowledge transfer and collaborative opportunities for business to engage in the growth and development of Irelands bioeconomy by supporting companies and producers in the development of circular and sustainable business models and management systems.

The mission of the AgriTech Ireland Cluster (fig 7.15) is to accelerate sustainable growth of Irelands agricultural technology companies and industry players by facilitating engagement with R&D research centres. Economies across the globe will be challenged to meet the rising need for food production. Industry must become smarter using technology to add value to our food supply chains. Irish Agri-tech companies will play an increasingly important role in these food supply chains. The purpose of the cluster is to accelerate innovation and the multi-regional growth of the AgriTech industry in Ireland and internationally.

Figure. 7.15: *AgriTech Ireland Cluster at Munster Technological University, Kerry*

Figure. 7.16: *Killybegs Marine Cluster at Atlantic Technological University, Letterkenny*

The Killybegs Marine Cluster (fi. 7.16) is an industry-driven marine cluster that aims to build capacity with businesses working within the blue economy to support member companies to improve their competitiveness, internationalise their businesses, and maximise their efficiency and productivity. The core objectives of the Killybegs Marine Cluster are to establish new business opportunities in international markets, foster skills and talent, and provide its members with direct access to R&D for innovation whist building a business and community partnership founded on mutual trust. Due to the geographical position of Killybegs on the Northwest coast of Ireland, the port provides easy access to the richest fishing grounds in Europe with a vision for developing innovation in sustainable commercial fishing and valorisation of blue economy opportunities. Killybegs is also geographically renowned as having one of the most sustained offshore wind speeds in Europe.

Figure. 7.17: Wood Connect Cluster at Atlantic Technological University, Connemara

The Wood Connect cluster (fig. 7.17) is supporting enable Ireland's wood construction, interiors and wood science sectors to scale rapidly and sustainably through: Improved competitiveness, productivity, and collaboration; Development and adoption of innovative technologies; Efficient creation of novel products and services; Enhanced access to talent, R&D capacities and international support. This cluster aims to assist Ireland in achieving Irelands reduced carbon emission targets by promoting wood as a sustainable material. The objective is to promote increased engagement and connectivity between knowledge providers, agencies, and SMEs, to support industry with their research and educational needs, in a focused and meaningful way that will foster increased productivity and drive competitiveness, R&D, Innovation, and increased growth and export activity.

Opportunities in the Irish context

Biorefineries

Ireland currently imports approximately 3 million Tonnes of animal feed per annum. The EU aims to increase self-sufficiency or European agriculture through the availability of locally available feeding sources of European agriculture (European Commission, 2018). Green biorefineries are emerging as sustainable technologies that could help to reduce carbon dioxide and other greenhouse gas emissions, while improving resource efficiency of grass and other green biomass sources. These technologies can also produce high value products and utilize waste streams.

Through the EIP-AGRI Biorefinery Glas[153] 'Bringing the Bioeconomy to Irish Farms' project, MTU together with partners UCD, GRASSA, Carbery and Barryroe have been demonstrating how small-scale mobile biorefineries can convert grass into different product streams for use in many different applications. Through this multifaceted lens, grass can be a source of protein or amino acids, sugars (mono-, di-, poly- and oligosaccharides), fibres, organic acids, lipids and minerals, providing Ireland with a vast opportunity to maximise land use and grasslands

Recent studies demonstrate that protein produced using green biorefinery is considerably more sustainable than soybean meal imported from Brazil which incurs large emissions in production phase (e.g., from land use changes and deforestation), and transport phase (Franchi et al, 2021). Locally produced animal feed protein can compete comparably with imported soybean protein in terms of both cost and performance. Grass protein concentrate has already partially replaced soybean meal in Ireland's pig feed diets (Ravindran et al, 2021). Ireland has an abundance of Agri protein feed suppliers, who could potentially become strategic market partners for green biorefineries.

153 https://biorefineryglas.eu/

Marine Sector

Ireland's marine area is one of the largest in the EU with approximately 450,000 km2 of this seabed territory area falling within 200 nautical miles of Ireland's shores making it part of our Exclusive Economic Zone (EEZ). As a maritime nation this territory encompasses an area approximately ten times the size of Ireland's landmass. Significant opportunities arise through the development of a sustainable maritime or 'blue' economy (Marine Institute, 2018) supported by the strategic alignment between DAFM and Marine Institute objectives and actions (Marine Institute, 2021). Blue Carbon, carbon sequestered or stored by the ocean and in vegetated habitats around coastal regions has been identified as one of the ways in which marine and coastal ecosystems can reduce the impacts of climate change. Aquaculture is the fastest growing animal food producing sector in the world and is an increasingly important contributor to global food supply and economic growth. Emerging ocean-based industries have high growth potential and contribute to addressing global challenges such as energy security, environment, climate change and food security in the sustainable growth of the Blue Economy. (SAPEA, 2017). The extraction of algae biomass is becoming increasingly important as it is expected to represent an efficient alternative to increase the European biomass production potential. Algae are mainly utilized by the food and chemical industry and Increased investment in sustainable farming of algae has become crucial. In the EU, farming of algae is still at an early phase in the EU and requires further developments at the technological, operational, biological knowledge and economic and legislative levels.

AgroBRIDGES short food supply chains

The agroBRIDGES project has developed a suite of tools specifically aimed at supporting short food supply chain development to empower farmers and enable them to make more sustainable decisions for their businesses. These tools are designed to inform and educate farmers, support sustainable business model selection, create effective communication strategies (including identifying unique selling points), best practice case studies, strategic networking (including event support for event organisations) and bespoke tools for enabling collaboration in the proposing of new business ideas and posting available services and facilities. The agroBRIDGES toolkit will be available across Europe in 2023 providing a blueprint addressing AgClimatise Action 13 which states that for the development of supply chains where new market opportunities arise this requires support to develop new business models, scaling capabilities and processing technologies.

Wool

A 1% increase of European wool-based products in the market share of the global construction, textile and plastics markets could generate a revenue for the European wool-based bioeconomy in the scale of EUR 10 to 60 billion (EC, 2018). Wool as a sector is often overshadowed by the meat sector particularly in assessments of greenhouse gas emissions (Gerber et al,, 2013). Alternative fibres identified for their lower environmental impacts also include organic cotton, hemp, and flax. The 'Department of Agriculture, Food and the Marine; Review of Market Opportunities for Irish Grown Wool Based Products'

2022 report states that across the world, natural fibres are receiving attention for their sustainability and unique natural properties. Sheep's wool is no exception and is one of the natural and renewable resources widely used in a range of applications. Wool has a unique composition that makes it applicable to many markets including horticulture, packaging, insulation, textiles, cosmetics, filled products and composites. This provides opportunities for Ireland to accelerate and develop these opportunities as is recognised with the establishment of the Irish Wool Council to champion the Irish grown wool brand domestically and internationally. In parallel, a dedicated panel of experts have merged to create the Wool Hub Ireland to signpost collaborative R&D partnerships and provide mentoring services to support the development of commercialising and scaling of micro-enterprises, SMEs and industry projects (Fig. 7.18).

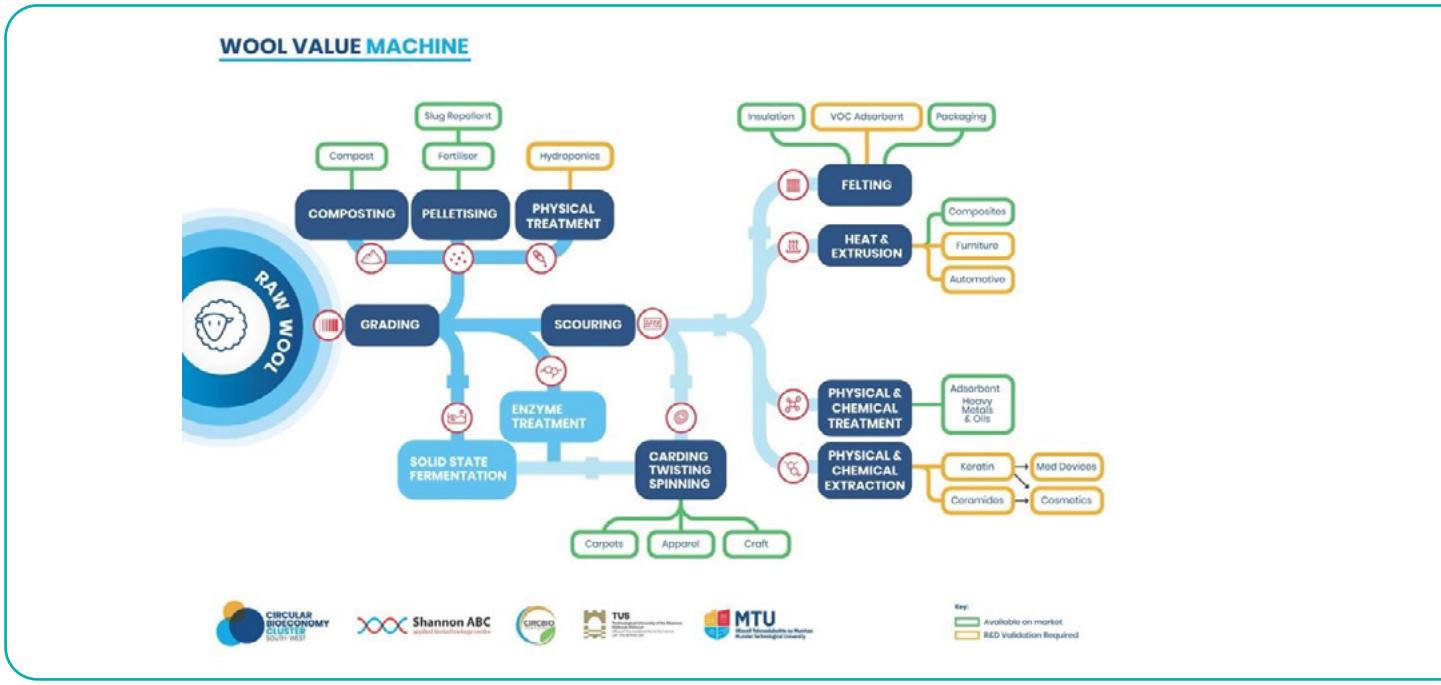


Figure. 7.18: *Wool Value Machine opportunities for development in the Irish wool industry.*

Valorsation of Industrial Waste Biomass

SYMBIOMA.eu is a three-year project (2019-2022) financed by the EU Northern Periphery and Arctic Programme to develop technology innovations and business models for valorisation of industrial waste biomass. The project which includes Ireland, provides micro-, small- and medium-sized enterprises in rural and sparsely populated areas with resource-efficient, innovative products and services for developing the circular bioeconomy exploring industrial symbiosis approaches to the utilization of fish industry side streams, valorisation of spent grain from the brewing industry and distilling side streams, potatoes side streams. A prime example of creating a new value chain is again demonstrated by the Irish brand BiaSol. The rapid growth of craft brewing across Ireland led to a rising side stream supply of brewers' spent grains which BiaSol are transforming into a fibre rich powder to add to smoothies, baked goods and porridge.

Agriculture

The 2021 Climate Action Plan committed the government to incentivize increased organic farming and diversification into forestry, biomethane and energy production. The full suite of land use diversification options to consider can support the just transition to lower emissions range from horticultural production, protein crop production, organic farming, energy crop production to afforestation and agroforestry. Dairy is a burgeoning industry following the global population growth, resulting in generation of waste such as wastewater (from cleaning, processing, and maintenance), whey and sludge, which are an environmental hazard if disposed of inappropriately. Incorporating a more circular bioeconomy into pasture-based production systems reduces environmental pressures and increase production efficiency on Irish farms. However, these components are rich in nutrients, organic and inorganic materials, hence could be reutilised and contribute to a circular bioeconomy. Microbes resulting from the process of utilization and valorisation of dairy waste with aerobic and anaerobic treatments offer a more sustainable and green method to produce biofertilizers, biofuels, power, and other biobased products.

Forestry and Eco-systems services

Irelands temperate climate is perfectly suited for tree growing yet is one of Europe's least forested countries. The European average for forested land area is 40% however currently in Ireland this figure is just less than 11%. Despite a relatively small national forest estate by European standards, the sector in Ireland is well optimised and technologically highly advanced (COFORD, 2017). Sustainable forest management links the concepts of circular and bioeconomy concepts by both sequestering carbon during growth and providing renewable materials which store this carbon while they are used, reused and recycled. Forest biomass can be used to make products that can displace materials such as concrete, steel, aluminium. A triple effect is that end of life sustainably sourced forest-based biomass products can be converted into energy sources for generating heat and or electricity.

AgClimatise Action 14 states a requisite increase afforestation levels to 8,000 ha per year with the planting of a range of different species to ensure adaptive and resilient forest stocks. There is a need to examine new opportunities for the forestry sector through the replacement of unsustainable raw materials in construction and packaging with bio-based materials, polymers, fibres and composites and for providing more sustainable innovations in sectors such as forestry-based textiles, furniture and chemicals, and developing new business models based on the valuation of forestry ecosystem services (Linked to Action 12). To create to infrastructure to support this requires the construction of 125 km of new forest roads per year to facilitate the mobilisation of biomass and harvested wood products, supporting the transition to a low carbon economy. Encourage the diversification of different types of forestry systems such as agroforestry and continuous cover forestry and continue to fund knowledge transfer groups promoting sustainable forest management.

Overall recommendations for Irish organisations

More support is needed for companies to investigate the potential of circular economy opportunities in their own organisation and value chain. National and regional authorities play a key role in empowering industry through effective policies to facilitate sustainable circular actions in the long term. Additionally, public agencies can support industry in educating and re-skilling their workers who are flexible and can adapt to the circular skills required in the agrifood sector in this rapidly evolving time for the sector.

Further explore methods to transform your production operations, there is a need for a shift in thinking away from traditional linear production models to more radical and regenerative self-sufficient business models, which is likely to require innovation and open collaboration between all stakeholders.

Collaborate and share knowledge, there is a significant need for companies to come together and transparently share insights and best practices to foster more effective circular solutions in the agri-food sector in Ireland. Stay active and continuously monitor developments in this space, to ensure your organisation is at the forefront of circular biobased solutions both nationally and internationally.

Accelerate your action, circular solutions can offer the potential to reduce your waste and associated costs, while also building more resilient supply chains, adhering to environmental regulations and satisfying a growing market demand.

7.4 References

- Ag Climatise A Roadmap towards Climate Neutrality (2020) Department of Agriculture, Food and the Marine, Kildare Street, Dublin 2, Ireland
- AgriChemWhey (2020) About AgriChemWhey. Available [https://www.agrichemwhey.com]
- Arla Foods. (2019) Arla makes over one billion pieces of packaging more sustainable across Europe | Arla. News & Press. https://www.arla.com/company/news-and-press/2019/pressrelease/arla-makes-over-one-billion-pieces-of-packaging-more-sustainable-across-europe-2869447/
- Attard, J. & O'Connor, T. (2022) Food Loss and Waste from Farming, Fishing and Aquaculture in Ireland. Environmental Protection Agency Report 410. Available [https://www.epa.ie/publications/research/waste/Research_Report_410.pdf]
- Avatium. (2020) PEF as a multilayer barrier technology: a sustainable way to enable long shelf life in PET bottles - Avantium. Publication. Available https://www.avantium.com/publication/pef-as-a-multilayer-barrier-technology-a-sustainable-way-to-enable-long-shelf-life-in-pet-bottles/
- Barret, A. (2018). Irish Find a Way to Compost PLA at Home. Bioplastics News, 52(18). Available https://doi.org/10.1021/ACS.EST.8B02963
- Bio-based Industries Joint Undertaking. (2020). AgriChemWhey. Agrichemwhey. Available https://www.agrichemwhey.com/
- Broderick, S. & Gibson, C. (2019) Reducing Commercial food Waste in Ireland. Environmental Protection Agency Research Report 282 Available [https://www.epa.ie/publications/research/waste/Research_Report_282.pdf]
- Bröring, S. & Vanacker, A. (2022) Designing Business Models for the Bioeconomy: What are the major challenges? EFB Bioeconomy Journal, Volume 2, 100032, ISSN 2667-0410, https://doi.org/10.1016/j.bioeco.2022.100032.
- Caldeira, C., Vlysidis, A., Fiore, G., De Laurentiis, V., Vignali, G. and Sala, S. (2020) Sustainability of food waste biorefinery: A review on valorisation pathways, techno-economic constraints, and environmental assessment. Bioresource Technology 312:123575 doi: 10.1016/j.biortech.2020.123575.
- Carbery (2023) Protein Innovation. Available [https://www.carbery.com/nutrition/insight-innovation/protein-innovation]
- COFORD, (2017), Department of Agriculture, Food and the Marine, Agriculture House, Kildare Street, Dublin 2, Ireland.
- COOPID (2022a) COOPID Austrian Success Case: Pelletierung. Available [https://interactiveplatform.coopid.eu/archivos/portfolio-items/coopid-austrian-success-case-pelletierungsgenossenschaft-egen]
- COOPID (2022b) COOPID Irish Success Case: Carbery. Available [https://interactiveplatform.coopid.eu/archivos/portfolio-items/coopid-irish-success-case-carbery]
- DECC (Department of Environment, Climate Change and Communications) (2022) Ireland's National Food Waste Prevention Roadmap 2023-2025. Department of Environment, Climate Change and Communications, Dublin, Ireland.
- European Bioplastics. (2015). What are bioplastics? Material types, terminology, and labels an introduction. In European Bioplastics. https://docs.european-bioplastics.org/publications/fs/EuBP_FS_What_are_bioplastics.pdf
- EC (European Commission) (2022). EU policy framework on biobased, biodegradable, and compostable plastics. European Commission Communications, 682(30.11.2022).
- EC (European Commission) (2020) Guidance on Reporting of Data on Food Waste and Food Waste Prevention according to Commission Implementing Decision (EU) 2019/2000. EC, Brussels, Belgium.
- EC (European Commission) (2018) A sustainable bioeconomy for Europe@ strengthening the connection between economy, society, and the environment 2018, European commission [https://knowledge4policy.ec.europa.eu/publication/sustainable-bioeconomy-europe-strengthening-connection-between-economy-society_en]
- EC (European Commission) Directorate-General for Research, and Innovation, (2019) Bio-based products: from idea to market "15 EU success stories". Publications Office.
- EC-JRC (European Commission Joint Research Centre) (2020) Brief on Food Waste in the European Union. European Commission Joint Research Centre, Ispra, Italy.
- EPA (Environmental Protection Agency) (2022) Food Waste Statistics for Ireland. Available [https://www.epa.ie/our-services/monitoring--assessment/waste/national-waste-statistics/food/#d.en.101376]
- EPA (Environmental Protection Agency) (2017) Food Waste Charter for Ireland. Available [https://foodwastecharter.ie/]

- FoodCloud (2023) Rescuing good food to help people and planet. Available [https://food.cloud]
- Franchi, C., Brouwer, F., Compeer, A., (2021) 'LCA summary report Grass protein versus Soy protein', Interreg GrasGoed, accessed online 10/12/2022 [https://www.coebbe.nl/app/uploads/2021/12/GrasGoed-LCA-summary-report-chicken-feed-protein-final.pdf]
- Gaffey, J., McMahon, H., Marsh, E., Vehmas, K., Kymäläinen, T., & Vos, J. (2021). Understanding Consumer Perspectives of Bio-Based Products—A Comparative Case Study from Ireland and The Netherlands. Sustainability 2021, Vol. 13, Page 6062, 13(11), 6062. https://doi.org/10.3390/SU13116062
- Gaffey, J., McMahon, H., Marsh, E., & Vos, J. (2021). Switching to Biobased Products – The Brand Owner Perspective. Industrial Biotechnology, 17(3), 109. https://doi.org/10.1089/IND.2021.29246.JGA
- Gatto, F.; Re, I. Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the SME Instrument Support. Sustainability 2021, 13, 1899. https://doi.org/10.3390/su13041899
- Gerber, P.J., Stenfeld, H., Henderson, B., Mottet, A., Opio, C., Felucci, A. & Tempio, G. (2013) Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities, Food and Agriculture Organization of the United Nations (FAO)
- Jernström, E. Karvonen, V. Kässi, T. Kraslawski, & A. Hallikas, J. (2017) The main factors affecting the entry of SMEs into bio-based industry, Journal of Cleaner Production, Volume 141, Pages 1-10, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2016.08.165
- Klein, O., Nier, S. & Tamásy, C. (2022) Towards a Circular Bioeconomy? Pathways and Spatialities of Agri-Food Waste Valorisation. Tijdschrift voor economische en sociale geografie 113:194-210 doi:10.1111/tesg.12500
- Lee Strand. (2020). Ireland's first 100% renewable 2 litre milk carton. Lee Strand. Available https://leestrand.ie/environment/our-sustainable-packaging/
- Lyons. (n.d.). Sustainabili-Tea | Lyons. Available https://www.lyonstea.ie/sustainabili-tea/
- Marine Institute (2018). Marine Institute Strategic Plan 2018-2022; Building Ocean Knowledge, Delivering Ocean Services. Marine Institute, Ireland.
- Marine Institute (2021). Marine Institute Alignment with Department of Agriculture Food & the Marine Statement of Strategy 2021-2024
- Makkar, H.P.S. (2017) Opinion paper: Food loss and waste to animal feed. animal 11:7:1093-1095 [https://doi.org/10.1017/S1751731117000702]
- McCarthy, S., Serebrennikov, D., Bradly, J. & Brychkova, G. (2022) Waste not, want not. TResearch 17:1: Spring [https://www.teagasc.ie/media/website/publications/2022/TResearch-Spring-2022.pdf]
- National Smart Specialisation for Innovation 2022-2027, (2022), Department of Enterprise, Trade & Employment, 23 Kildare Street, Dublin 2, Ireland.
- O'Brien, A., Fuller, R., O'Connor, T. & Attard, J. (2022) Surplus Food Redistribution - An Opportunity to Reduce Farm Level Food Waste. Dept. of Agriculture Food and the Marine, Dublin, Ireland.
- Origin Green. (2021). Aldi first to launch new home compostable steak trays in Ireland. News and Events. Available https://www.origingreen.ie/news-and-events/aldi-first-to-launch-new-home-compostable-steak-trays-in-ireland/
- Ornua Ingredients (2018) Whey Permeate. Available [https://www.ornua.com/wp-content/uploads/2018/07/whey-permeate.pdf]
- Project, B. (2021). Understanding the main barriers perceived by brand owners when switching to bio-based approaches (Issue 887727).
- Teagasc. (2016). Agriculture and Food Development Authority. Agriculture in Ireland. Available https://www.teagasc.ie/rural-economy/rural-economy/agri-food-business/agriculture-in-ireland/
- Technological University Dublin. (2021). Leaf No Waste Progresses to the Seed Phase of the SFI Future Innovator Prize. News. Available https://www.tudublin.ie/research/news/leaf-no-waste-progresses-to-the-seed-phase-of-the-sfi-future-innovator-prize-.html
- Timoleague Agri Gen (2023) Welcome to Timoleague Agrigen. Available [https://timoleagueagrigen.ie/]

- Rajendran, Ó Gallachóir & Murphy (2019) The Role of Incentivising Biomethane in Ireland Using Anaerobic Digestion. Environmental Protection Agency Research Report 279. Available [https://www.epa.ie/publications/research/waste/Research_Report_279.pdf]
- Ravindran, R.; Koopmans, S.; Sanders, J.P.M.; McMahon, H.; Gaffey, J. Production of Green Biorefinery Protein Concentrate Derived from Perennial Ryegrass as an Alternative Feed for Pigs. Clean Technol. 2021, 3, 656-669. https://doi.org/10.3390/cleantechnol3030039
- Reike, D., Vermeulen, W.J. and Witjes, S. (2018) The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resources, conservation, and recycling 135:246-264.
- Reim, Wiebke, Vinit Parida, and David R. Sjödin. 2019. "Circular Business Models for the Bio-Economy: A Review and New Directions for Future Research" Sustainability 11, no. 9: 2558. https://doi.org/10.3390/su11092558
- Review of Market Opportunities for Irish Grown Wool Based Products (2022) Department of Agriculture, Food and the Marine, Kildare Street, Dublin 2, Ireland.
- SAPEA, Science Advice for Policy by European Academies. (2017). Food from the oceans: how can more food and biomass be obtained from the oceans in a way that does not deprive future generations of their benefits? Berlin: SAPEA. doi:10.26356/foodfromtheoceans
- Watson, D., Kaarsberg, S., & Bauer, B. (2022). Synopsis Report on the Consultation on the Policy Framework on biobased, biodegradable, and compostable plastic. Available https://doi.org/10.2779/126536
- WRAP (Waste and Resources Action Programme), EU-REFRESH, Timmermans, T. and Wunder, S. (2020) Building Partnerships, Driving Change: A Voluntary Approach to Cutting Food Waste. EU-REFRESH, Wageningen, Netherlands. [https://wrap.org.uk/resources/guide/building-partnerships-driving-change-voluntary-approach-cutting-food-waste

8. The Agri-food Funding Ecosystem

Authors:

Marcela Navarro | Steve Evans

Credit: Shutterstock

Acknowledgements

Project X would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Marcela Navarro and Steve Evans

Reviewers

Saskia Visser (EIT Climate KIC), Luke Baker (EIT Climate KIC).

How to cite this Chapter:

Project-X The Agri-food Funding Ecosystem Chapter 8 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Glossary

Agriculture	Agriculture is not crop production as popular belief holds. It is the production of food and fiber from the world's land and water. Without agriculture it is not possible to have a city, stock market, banks, universities, church or army. Agriculture is the foundation of civilization and any stable economy." - Allan Savory
Regenerative Agriculture	At its core, regenerative agriculture is farming and ranching in harmony with nature.
Assets	A real asset is a tangible investment that has an intrinsic value due to its substance and physical properties. Commodities, real estate, equipment, and natural resources are all types of real assets.
Blended Finance	Blended finance is typically used to describe the strategic use of development finance for the mobilisation of additional private finance towards sustainable development. They are essentially debt instruments, and they often have both equity- and debt-like characteristics.
Project Bonds	Project bonds are standardised securities that finance individual stand-alone infrastructure projects. Project bonds are a growing area of project finance and provide a potential solution to finance projects with long-term debt.
Cash	Cash and cash equivalents are generally among the most liquid investments, often with some of the lowest risk/return profiles, depending on the investment term.
Catalytic	Causing, involving, or having a catalytic effect means causing things to happen or increasing the speed at which things happen
Carbon Credits	A permit which allows a country or organization to produce a certain amount of carbon emissions, and which can be traded if the full allowance is not used
Farmland	Real assets, such as farmland, constitute the primary asset class through which regenerative food and agriculture is currently being financed. Agricultural land management is central to soil health.
Fixed income	Investors have opportunities to be lenders themselves by investing in debt instruments that return a yield on a regular, fixed interval. Fixed income investments play an important role in diversified portfolios.
Green Bonds	Green bonds are corporate bonds, project bonds, and sub-sovereign bonds that finance investment in green infrastructure assets
Lever	A big category of work. A key area of focus where investors and philanthropists can leverage their resources to spur transformational action to increase adoption of <regenerative agriculture>
Leverage	Use (something) to maximum advantage
Leverage points	"leverage points" are key in systems analysis. LP are places within a complex system (a corporation, an economy, a living body) where a small shift in one thing can produce big changes in many things
Intervention Points	Points of intervention are specific places in a system where a targeted action can effectively open the way to transformation, in order to have the greatest impact.
Maturity Mistmatch	In the context of land regeneration we are applying this concerto to short-term funding of long-term assets
Mezzanine financing	A form of hybrid financing that blends features of debt and equity. Mezzanine loans are subordinate tranches of debt often used in project finance to provide credit enhancement for senior debt tranches. Mezzanine is higher risk and pays higher yields than senior issues and often includes equity participation.
Philanthropic Capital	Philanthropic capital is funding delivered as either a gift with no expectation of financial return or an asset with a less than market rate return-on-investment (ROI), that is intended to generate social impact. The most common source of philanthropic capital is grants, which are most often given out by foundations, corporations, or government agencies.
Philanthropic Loans	Philanthropic loans are a type of philanthropy. They are an investment for impact not for financial return.

Philanthropic risk	The certainty of achieving a result or impact. For example, supporting the pilot of a new initiative, it would be considered higher risk as it has not been tested before. Supporting a well evidenced approach, it would be considered lower risk. Certain categories of philanthropy activity are inherently risky, e.g. advocacy and systems change. These activities, however, often offer potentially higher rewards, due to the opportunities for leverage
Philanthropic leverage	Maximising the impact of donor contributions, with the same donation value. A method of grant-making whereby an investment is made in a charity or other organisation with the express purpose of attracting funds or other forms of support
Private Equity / Venture Capital	Private equity and venture capital provide opportunities to invest directly into private companies working on business and technology solutions across food and agricultural value chains. Investors can gain exposure to the asset class by either investing directly in companies themselves or investing as a limited partner in a private equity or venture capital fund or a fund of funds.
Public equity	Investors can purchase shares of the listed equities of publicly traded corporations. Public equity usually constitutes the largest component of an investor's portfolio. Opportunities for impact are particularly through investment selection and shareholder advocacy.
Regenerative Finance - ReFi	Regenerative finance uses money as a tool to solve systemic problems and regenerate communities and natural environments. It is based on this theory of regenerative economics. ReFi is the regenerative finance movement forming at the intersection of the third evolution of the internet (Web3)
Retired carbon	After an organisation or an individual buys a carbon credit, the credit is permanently retired so it can't be reused.
Carbon Avoidance - Carbon removal	Carbon removal removes the carbon that has already been emitted from our atmosphere. Carbon avoidance seeks to prevent carbon from being emitted in the first place.
Charity	A nonprofit organisation whose main goal is to improve social or environmental welfare
Donor	A person or organisation who decides to donate something, particularly to charity
ESG	ESG stands for Environmental, Social, and Governance factors. The acronym is often used in sustainable and ethical investment strategies.
Grantee	A person or entity that receives a grant
Impact Investment	An investment designed to deliberately generate both a positive financial, environmental and social return
Philanthropic Leverage	Using a donation to unlock or influence a larger amounts of funds.
Public equity	Investors can purchase shares of the listed equities of publicly traded corporations. Public equity usually constitutes the largest component of an investor's portfolio. Opportunities for impact are particularly through investment selection and shareholder advocacy.
Technical Assistance	Technical assistance, also known as "TA" is the process of providing targeted support to an entity with a development need or problem. It is an effective method for building the capacity of an organisation and it is commonly used in the Development finance ecosystem.
SDG	Sustainable Development Goals
Systemic Change	Systemic change is where relationships between different aspects of the system have changed towards new outcomes and goals. And it's driven by transformational, not incremental change.
Web 3.0	Web3 is an internet owned by users. It is the concept of the next generation of the web, in which most users will be connected via a decentralized network and have access to their own data.

The Agri-food Funding Ecosystem

The agri-food sector is one of Ireland's most important indigenous manufacturing sectors. It includes almost 700 food and drinks firms throughout the country that export food and seafood to more than 160 countries worldwide, and that source c 74% of raw materials and services from Irish suppliers.

This report is a review and synthesis of what is hidden in plain sight. It is not a description of a new financial instrument to fund Ireland's Net Zero. We do not only want to believe that there is a key intervention point to fund this transformation, where the 'one euro', the 'one heartbeat' and the 'one second', that can be deployed in the agri-food sector could generate a multiplicity of changes with positive results for people, nature, and the bottom line. We also want to highlight in this report, key aspects to achieve this multiplicity of changes, at the scale and pace that is needed.

Developed using system logic, the chapter considers a number of elements that are relevant to the mobilisation of funds to the global agri-food sector, based on our analysis. These include, in addition to relevant funding instruments and blended finance mechanisms, emerging trends, collaborative approaches and the 4 order challenges.

This report aims to highlight a key intervention points and the relevant leverage points required to accelerate the mobilisation of funds to transform the agri-food sector in Ireland. The views expressed in this research report are those of the authors.

8.1 The Agri-food Funding Ecosystem – General Trends

> **"Climate-friendly agricultural practices could mitigate nearly 170 $GtCO_2e$, while generating a nearly $10 trillion net financial return"**[154]

To quote Sir David Attenborough "*Never before have we had such an awareness of what we are doing to the planet, and never before have we had the power to do something about that.*"

We believe funding a system such as the agri-food sector requires a system's approach. A whole system's management that will enable the mobilisation of funds to do more, better, and faster. Before exploring key financing mechanisms directly associated with the Agri-Food sector, it is important to consider the general trends and key influencing forces in the funding ecosystem globally. In this section we describe key trends that are or will soon shape the agri-food funding space.

154 https://croataninstitute.org/resources/ Sept 2019

A "whole system" pathway. Food security as an interconnected problem is a top priority in the agenda of global gatherings. It is not a surprise it is once again included in the WEF meetings for 2023[155]. A recent FAO Report on the Future of Food and Agriculture[156] warns that without broader environmental and socioeconomic changes, building and maintaining sustainable agri-food systems and ultimately feeding the growing population, will not be feasible. Non-traditional funding partnerships are emerging, to leverage a wider range of assets and accelerate deployment of third-party capital in key intervention points in the value chain.

Changes in the regulation are contributing to the reduction of the gap between green washing, green wishing and green investing. "It doesn't matter if you market all of your products as sustainable or none of them—it covers all of them." It has been almost two years since the EU began a 'sustainability revolution' and the impact of EU taxonomy SFDR[157], including Article 9 is starting to make a difference. The UK went further by becoming the first country in the world to force disclosures to be aligned with the Task Force on Climate related Financial Disclosures (TCFD). These will be mandatory by 2025. Since the introduction of SFDR, already, numerous public and private firms are removing their ESG claims. Others are looking to address the gap and formalise all requirements to fall under Article 9 of SFDR, also referred to as "dark green"[158]. The revolution is just starting and with it a number of changes and behaviours are starting to shape the funding world.

Regenerative agri-food, a tangible opportunity to untap $10 trillion in net financial returns. The 2020 Soil Wealth Report[159] estimated that more than $700 billion in investments will be needed in the USA alone, over the next 30 years, to scale the regenerative agriculture market — and that investment will generate $10 trillion in net financial returns. Although there was a significant increase in funds and funding allocations to regenerative, from 2018 to 2020, the gap is significant and the opportunity for healthy returns is tangible.[160]

Covid, and the war in Ukraine, like many other shocks before them, have exposed the agri-food industries to critical dependencies, exposing critical vulnerabilities in entire value chains. Funders are becoming more aware of the intrinsic risks of the so-called externalities and the direct correlation with leverage and returns. The need to account for the true cost of supplies in a value chain is becoming a priority for funders. Traditional cost models are being re-evaluated and the 'True Cost of Low Cost' is a nascent movement within the procurement world. When companies and investors understand the magnitude of the losses they could face from supply chain disruptions, they will be in a better position

155 https://www.weforum.org/agenda/2023/01/future-food-farming-fao-agrifood/
156 https://www.fao.org/documents/card/en/c/cc0959en/
157 https://eur-lex.europa.eu/eli/reg/2019/2088/oj
158 Morningstar: Article 9 funds still account for a tiny 2.8 % of the overall EU fund universe
159 Soil Wealth Report, Croatan Institute - https://croataninstitute.org/wp-content/uploads/2021/03/soil-wealth-2019.pdf
160 CREO Syndicate's report Unlocking Investments in Regenerative Agriculture.

to calculate how much to invest in mitigation. As McKenzie wrote "Companies can expect disruptions to erase half a year's worth of profits or more over the course of a decade".[161] This growing trend is defining portfolio allocations significantly.[162]

A new group of conscious investors seeking more than just capital returns is emerging. Capital allocators that look at some of the same public and private benefits that also drive farmer and consumer interest[163]is growing. This group of diverse funders including philanthropist, impact investors and private capital, is increasingly looking to channel a larger proportion of their portfolio to address key planetary, soil and health challenges. They are also becoming more aware of the increasing monetisation value of the agri-food sector – mainly the regenerative space.

Impact investing is a fast-growing source of capital which could be attracted to invest in regenerative and innovative Irish Agrifood projects. The GIIN estimates that more than 3,349 organizations currently manage the industry's USD 1.164 trillion in impact investing assets worldwide. [164] The report highlights two key areas of development in the market that are becoming increasingly prevalent to fund impact projects: green bonds and corporate impact investing.

Institutions actively unlocking the potential of soils. Governments contributions remain low. In 2020, in the USA market alone, $972 billion in capital flowed to agriculture from capital allocators, according to the USFRA Transformative Investment report[165]. The largest portion of that came from institutions, while government capital represented only a small fraction. Farmland received most allocations, followed by farm operating capital and agriculture value chain companies.

Hybrid becoming the new normal. New approaches are creating positive opportunities for catalytic funding for SMEs[166] in the agri-food community. The cultural gap between private and public funding, philanthropy and for profit is changing. Funding impact has caught the attention of multiple stakeholders in the funding space from philanthropy, impact investors, private debt, etc.

'Consciousness in Procurement' is emerging as an effective tool to future proof value chain performance"[167] and influence capital allocations. "This is about enhancing the act of buying (value chain supplies) with high levels of understanding, appreciation, and respect, in addition to the basics of quality, cost and speed". 'Consciousness fit' due diligence processes are nascent but being more closely

161 https://www.mckinsey.com/capabilities/operations/our-insights/supply-chains-to-build-resilience-manage-proactively

162 https://www.moodysanalytics.com/-/media/whitepaper/2019/creating-an-integrated-%20investment-value-chain.pdf

163 E.g. Health and nutrition, nutrient cycling, water retention, carbon storage, sustainable livelihoods, improved yield stability

164 GIIN – Sizing the Impact Investment Market 2022 - https://thegiin.org/research/publication/impact-investing-market-size-2022/

165 Transformative Investment in Climate-Smart Agriculture Unlocking the potential of our soils to help the U.S. achieve a net-zero economy FEBRUARY 2021 - https://usfarmersandranchers.org/wp-content/uploads/2021/02/USFRA-Transformative-Investment-Report.pdf

166 https://read.oecd-ilibrary.org/finance-and-investment/new-approaches-to-sme-and-entrepreneurship-financing/hybrid-finance-instruments-for-smes_9789264240957-9-en#page1

167 Edie – Dec 2020 https://www.edie.net/lessons-from-project-x-redefining-risk-and-fear-in-times-of-environmental-crisis/

looked at by industries to deliver performance, resilience and productivity, and funders to minimize risk and improve returns. Climate-related risks, a key element of 'consciousness in procurement' is, according to The Intergovernmental Panel on Climate Change (IPCC), increasing in many parts of the world, both in terms of magnitude of impact (should a given hazard materialize) and in terms of uncertainty.

Growing pressure from consumers to access healthy food produced in an ethical way is shaping the investment allocation market. Several consumer trends reports, including Mintel global Consumer Data[168], show that the most important factor determining good value is the nutritional benefit of food (chosen by a global average of 57% of adults). This was followed by 'made with natural ingredients', and in third place, whether a product 'is at a lower price than others'. Planet FWD[169] also highlights how consumers today are increasingly seeking to understand where their food comes from and how it was produced. Consumers want their food to also reflect their values – and today that means "good for people and planet". 55% of all growth in consumer-packaged goods (CPG) came from sustainably marketed products from 2015-2019. 69% of consumers have changed the products they use due to concern about climate change. These trends will continue to drive demand and premiums for regenerative food.

Consumer awareness of "regenerative" remains low – only 16% of consumers aged 16-44 are aware of regenerative agriculture, according to data from Planet FWD, but this number is growing significantly and therefore it is a key trend to consider.

A change in the narrative is becoming apparent, paving the way for a closer alignment between the philanthropic and the for-profit funding markets.[170] From sustainability to green (doing less harm), then moving to neutrality (doing no harm), and restoration (repairing damage) to regeneration (systemically creating the conditions for abundance where people and planet thrive). Impact investors and catalytic capital providers are incorporating these changes in the narrative - some with more robustness than others. What is clear is that there is an increasing level of awareness from the different funders, on the key connection between soil, human, planet and economic health. This is a creating an opportunity to bring closer together the philanthropic and the for-profit space, as well as the public–private funding cultures addressing terminology gaps, sharing knowledge and increase the understanding of risk, among other.

There is a growing awareness about the role of biodiversity and ecosystem services (or 'nature') as the foundation of our economy and the business disruptions, reputational risks, and systemic risks nature loss can cause.

168 https://www.mintel.com/blog/food-market-news/three-food-and-drink-trends-to-watch-out-for-in-2023
169 https://www.planetfwd.com
170 https://thefifthestate.com.au/columns/spinifex/moving-beyond-green-towards-regenerative-development/

Natural Markets is an emerging sector that could be the size of the world's third largest economy. A recent study from Taskforce[171] argues nature-based markets, including agriculture, voluntary carbon credits, conservation projects, and nature-based solutions for carbon sequestration, could be worth more than $7 trillion a year, making them equivalent to 8.6 percent of global GDP. The report details how more than half the calculated value comes from agricultural production alone. The study also found that an estimated 3 billion acres of privately owned assets is worth up to $8.6 trillion, 85 percent of which is agricultural land.

Carbon is transitioning from speculative to core in the regenerative agri-food space. Reforestation, grasslands regeneration and carbon credits are being closely looked at by different stakeholders in the Agri-food value chain as a new source of income and financing. Demand drivers of Carbon Credits and High Quality Carbon Credits (linked to true regeneration) is transitioning from something that is invisible and under-valued to one that is explicitly recognized, valued, and traded.

The decarbonisation journey, smoke carbon offsets, phantom credits, green washing and zero tolerance.

Two main issues in the decarbonisation journey that are worth noting. (i) Too early carbons: most companies are unfortunately buying carbon credits very early in the Net Zero journey. (ii) Smoke carbons or phantom carbons: It does not come as a surprise that the demand for early carbons is directly or indirectly influencing malpractices in the carbon market space. The very recent 9-month investigation from The Guardian[172] published January 2023, revealed that more than 90% of rainforest offset credits by Verra – one of the biggest providers - are likely to be "phantom credits". In fact out of the 94.9m of carbon credits claimed, only 5.5m represented real emission reductions. As the Guardian pointed out, the results are "disappointing and scary" and we will expect additional pressure on companies to show that the credits they buy are not only generating verifiable, additional, permanent climate change mitigation outcomes, but are also delivering transparent, measurable environmental and socio-economic co-benefits.

171 https://www.naturemarkets.net/publications/nature-in-an-era-of-crises

172 https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe

Table 8.1 summarises key general trends in the agri-food funding ecosystem.

Table 8. 1: *Agri-food Funding Ecosystem General Trends - Summary*

#1 A "whole system" pathway and interconnected systems 'A systems approach to enable high performing systems that are inherently self-sustaining, reciprocal and resilient'	#2 Regeneration 'A growing recognition that the economy, business and society don't sit apart from nature, but within it'	#3 Consciousness 'From reductionism and separation mindsets to abundance and unity, in the way we act, transact and transform'
• Food security as an interconnected global problem is a top priority in the agenda of global gatherings • Covid, and the war in Ukraine, like many other shocks before them, have exposed the agri-food industries to critical dependencies, exposing critical vulnerabilities in entire value chains.	• Regenerative agri-food, a tangible opportunity to untap $10 trillion in net financial returns. • Natural Markets an emerging sector the size of the world's third largest economy • There is a growing awareness about the role of biodiversity and ecosystem services (or 'nature') • Institutions actively unlocking the potential of soils. Governments contributions remain low • Consumer awareness of "regenerative" remains low	• Growing pressure from consumers to access healthy food produced in an ethical way is shaping the investment allocation market • Conscious investors. A new group of conscious investors seeking more than just capital returns is emerging. Hybrid funding structures becoming the new normal • 'Consciousness in Procurement' is emerging as an effective tool to future proof value chain performance" and influence capital allocations
#4 Regulatory Changes 'Key regulation enabling long lasting changes in the funding sector with positive impact to our climate our biodiversity and our people'	**#5 Transparency 'Zero tolerance will determine what is acceptable in the market'**	**#6 Narrative, Culture & Identity 'Addressing the language and cultural gaps in key asset classes and funder types'**
• Changes in the regulation are contributing to the reduction of the gap between green washing, green wishing and green investing.	• Carbon is transitioning from speculative to core in the regenerative agri-food space • The decarbonisation journey, smoke carbon offsets, phantom credits, green washing and zero tolerance	• A change in the narrative is becoming apparent, paving the way for a closer alignment between the philanthropic and the for profit funding markets

8.2 Key Financing Mechanisms in the Agri-food space

Achieving the SDGs and the Paris Agreement on climate change requires a transformative agenda for agriculture and food systems.

> **"Vast allocations of capital and an intentional focus towards generating positive impact are required right now if we are to achieve the UN Sustainable Development Goals by 2030 and to reach net zero emissions by 2050."**

In this section we describe the high level, the key financing mechanisms that we believe are relevant (on their own or blended) to fund the agri-food transition.

The landscape of providers of finance to agri-food is diverse. Different types of capital play a key role. Some of them are actively used in Ireland. Others are better established in other developed economies. In any case, there are significant amounts of funds available. Yet, not all funding types are adequate to fund key leverage points in the agri-food journey. further, the money is not arriving to the sector at the scale and pace that is required. We will focus on 4 main financing mechanisms (figure 8.1) that are actively used in the market (or growing rapidly), have a good degree of flexibility and risk tolerance, and can blend well with other instruments.

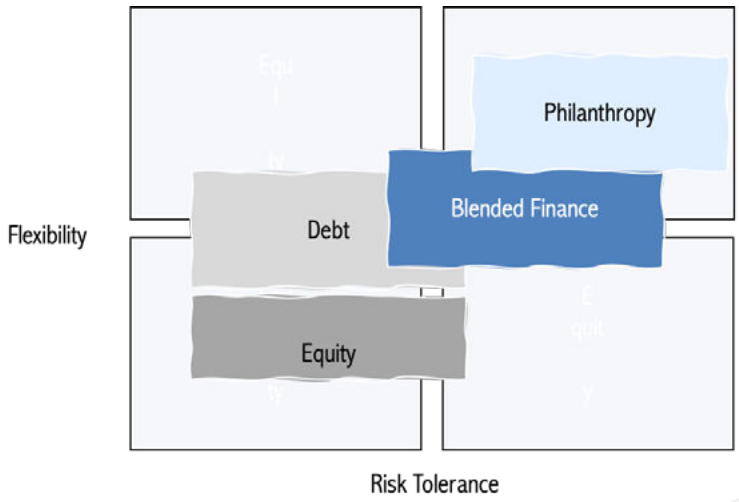


Figure 8.1: *4 Main financing Mechanisms in the Agri-food Sector*

Philanthropic Capital in Agri-food

The significant leverage value of Philanthropy

"We need to stop thinking of sustainability and returns being in opposition." Johnny El Hachem, CEO of Edmond de Rothschild.

Funding Mechanism		Key role	Current penetration In Irish agri-food sector	Flexibility	Risk Tolerance
1	Philanthropic Capital (PC)	PC plays a substantial role in minimising the risk of projects for future investment and attracting additional sources of funding	- Low	- Med/ High - High	- High

Philanthropic capital is in general, one of the most risk tolerant, flexible, and catalytic types of capital available. It is actively used in the development world and is continues to grow in key development economies like the USA, to fund and influence major transformations. In Europe, for example, the Philanthropic Capital Study, published in December 2022[173], highlights the importance of philanthropic capital and its role in the social economy in Europe.

The Philanthropy Market in Ireland

- The Philanthropy market is low compared to international standards, according to Niall O'Sullivan. Indecon, estimated the overall level of charitable giving in Ireland at c.€1.2bn annually.[174]
- Tax structures to promote larger-scale giving have not been implemented, there are very few new foundations, in short, little has changed in the past decade. Philanthropy in Ireland remains an untapped opportunity.

173 https://commission.europa.eu/content/evaluation-reports-economic-and-financial-affairs-policies-and-spending-activities/philanthropic-capital-study_en

174 https://businessplus.ie/interviews/advisory-group-will-raise-profile-for-philanthropy-in-ireland/

Philanthropy In The USA

Philanthropists are accountable for their own risk for their charitable giving - unlike businesses which are accountable to their shareholders, or governments which are accountable to the public. In the next section a description of key roles philanthropic capital can play in agri-food system funding today is given:

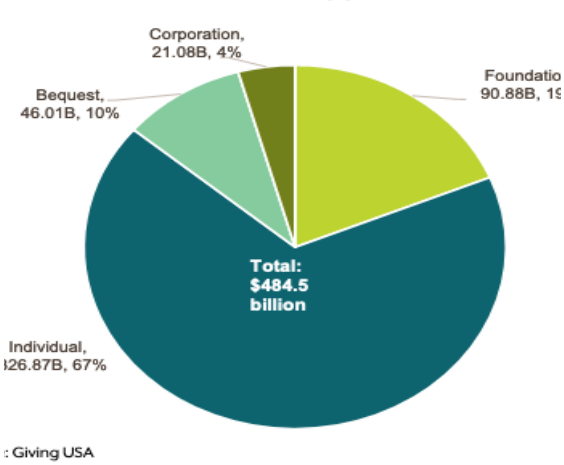


Figure 8.2: *US Philanthropy, 2001*

- Non-dilutive Capital: Philanthropy can serve as early stage, non-dilutive capital that supports R&D, demonstration and technical validation, and other roles to get companies further along and prepared for other types of investment.
- Infrastructure: As an underfunded space, grant capital can play a catalytic role funding set up costs – e.g. legal and permits, as well as land and facility acquisition that would otherwise be risky for projects and other investors.
- Leverage: Philanthropic capital can be used as matching funds to commercial funds, development organizations or government grants.
- New Tools: serving in a de-risking role, philanthropic capital can fund proof of concepts of new system funding models and financial tools to support the innovation required to fund regeneration and measure impact.
- Access to funding for under-represented stakeholders: Supporting communities and entrepreneurs who have been most deeply impacted by the extractive food system and providing capital to those under-served by the financial system.
- Access to knowledge: providing resources to fund technical validation, reducing the transition risk to regenerative outputs
- Confidence levels: by providing catalytic support to develop transparent and independent platforms to track regenerative funding and investment performance in complex agri-food system environments.

Philanthropy applied - Food Systems

- In the last 5 years there has been a significant increase in capital flowing to food systems, mainly in regenerative agri-food systems. Philanthropic funding follows this trend.
- SAFSF[175], formed by circa 100 private foundations, individual investors, community, and corporate foundations among other, reached $221.3 million in donations in 2022. This represents 69% increase since 2017. In 2022 donations across farms / farming systems increased.
- Regenerative agriculture was the largest area of giving and one of the fastest growing according SAFSF (figure 3).

175 https://www.agandfoodfunders.org/news-resources/safsf-reports/

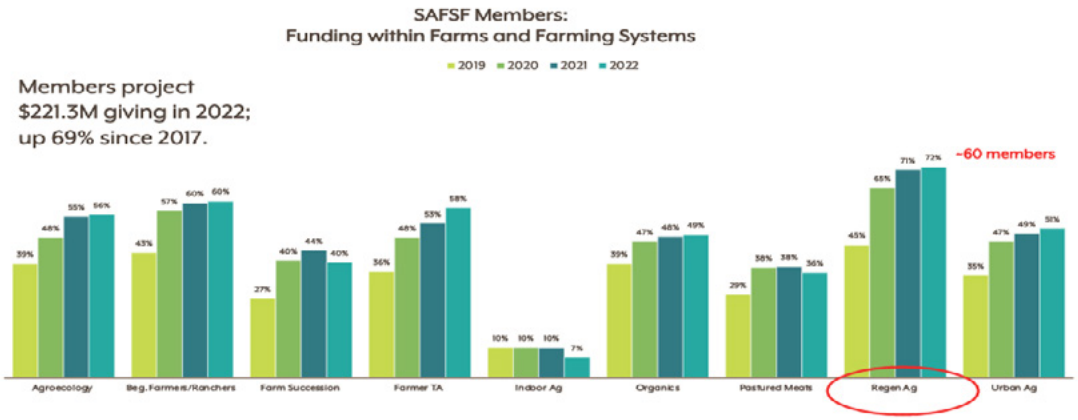


Figure 8.3: *SAFSF Funding within Farms and Farming Systems*

Donor Advised Funds (DAFs) - A promising capital source for Regenerative Agri-food

In line with global trends, Ireland also sees Donor Advised Funds as a flexible and low cost vehicles to manage charitable giving.[176]

- The value of grants from DAFs to charities around the world increased 28.2% to $45.74 billion in 2021.[177] This is a 28.2% increase from $35.68 billion in 2020.
- To quote Eileen Heisman, CEO of National Philanthropic Trust[178], "DAFs attract more people to engage in philanthropy and provide a very useful and convenient giving vehicle. More than one of every four DAF accounts was created in the last year." Charitable assets in all DAF accounts totalled $234.06 billion in 2021, a 39.5% increase from $167.81 billion in 2020. Number of DAF accounts in the U.S. totalled 1,285,801 in 2021, a 27.6% increase compared to 1,007,745 in 2020.
- To date, only an estimated $47.5B has been invested globally (around 7% of what's needed) to build a regenerative food and agriculture system over the next 30 years.[179]
- This gap has investors and fund managers considering DAFs, a funding source currently underutilized for impact.[180]
- DAFs are a good opportunity to leverage philanthropy to contribute to the funding pool for agri-food transition in Ireland.

176 Trends in Irish Philanthropy – The views of those who advise the Rich – PDF https://www.google.com/url?sa=i&rct=-j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=0CAQQw7AJahcKEwjwll3J2938AhUAAAAAHQAAAAQA-g&url=https%3A%2F%2Fwww.bl.uk%2Fbritishlibrary%2F~%2Fmedia%2Fbl%2Fglobal%2Fsocial-welfare%2F-pdfs%2Fnon-secure%2Ft%2Fr%2Fe%2Ftrends-in-irish-philanthropy-the-views-of-those-who-advise-the-rich.pdf&psig=AOvVaw3blx2DdrnGuRKzmJ3XxGC6&ust=1674563912011581

177 2022 Donor-Advised Fund Report Key Findings

178 https://www.nptrust.org

179 Electris, et al. Soil Wealth, Investing in Regenerative Agriculture across Asset Classes, 2021.

180 DAF is a tax-preferred philanthropic vehicle managed (or "sponsored") by for-profit and non for profit financial institutions. Organizations, families or individuals can establish a DAF with an initial tax-deductible contribution into the DAF, which is considered a charity that holds assets. A DAF fund is an alternative to direct grant or setting up a private foundation. It is an easy-to-establish, low cost, and a flexible structure for charitable giving

8.3 Debt financing and its role in agri-food

A traditional funding instrument with a significant potential for the sector.

"You need to be patient if you want to invest in the agri-food sector" Head of debt financing at a large cooperative bank.

	Funding Mechanism	Key role	Current penetration In the agri-food sector in Ireland	Flexibility	Risk Tolerance
2	Debt	• Includes loans, mezzanine and bonds • Provide patient capital funds to finance large projects • Fund short term funding gaps resulting of the cash flow conversion cycle – i.e. trade finance • Lower cost of fund vis a vis. mezzanine or equity	- Medium (deleveraging currently occurring)	- Medium - Med -Low	- Med -low - Low

Banks and corporates will continue to be an important source of lending to fund the needs of the agri-food sector.

- Key debt related instruments to fund complex transformations could include mezzanine loans, structured loans and bonds. The amount of funds required as well as the maturity mismatch in asset financing is a key gap and an opportunity.
- New players and instruments are emerging to finance sustainable, regenerative agriculture in both publicly traded debt securities, through bonds and bond funds, and in private markets, primarily through private debt funds or notes.
- Investors have also the opportunity to be lenders themselves by investing in debt instruments that return a yield on a regular, fixed interval.

Debt Financing in Ireland

Debt financing is an active instrument in Ireland. However, a significant deleverage has been occurring. Repayments have outstripped new lending. Central Bank data shows that credit advanced to Primary Industries, which includes agriculture, forestry and fishing and aquaculture sectors, was €781 million in 2020. This total remains less than the €824m in new lending in 2018 and €863m in 2017. New lending to primary agriculture represents 92% of this total, and fishing and aquaculture circa 6%. "Credit outstanding at the end of 2020 is €3.3 billion which is similar to 2019 but down from €4.7 billion at the end of 2010 and down from a peak of €6.4 billion in September 2008". Primary Agriculture accounts for 17% of the €19.8 billion outstanding debt held by Irish SMEs. [181]

181 Teagasc National Farm Survey, Preliminary results 2020 Table 2.14 Percentage of Farms with Borrowings and Average Debt, 2020

- Across all farm systems, almost two-thirds of farms have no farm- business related debt.
  - Six out of ten dairy farms had borrowings in 2020, compared to only three out of ten on cattle other.
  - A similar proportion of cattle farms had outstanding farm debt in 2020, compared with 2019.
- Tenor: Most of the farm-related debt was classified as medium to long-term in 2020 (76%).
  - 16 % of debts was related to leasing (or hired purchased).
  - 8% was reported as short- term debt e.g. overdrafts .
- Debt average:
  - Dairy farms have the highest level of debt. The average reported was €112,476, down from €117,039 in 2019.
  - Cattle rearing farms, average debt was €25,642, down 2.5% on 2019 levels.
- Debt to income ratio:
  - 3:1 reported for cattle farms (relatively high). To note 28% of cattle rearing farms reported having debt in 2020.
  - Sheep farms was significantly lower with 1:2.

8.4 Investing and its role in agri-food

Regenerative agriculture is fast becoming a focus for investors

"To create value, we invest inland, in growers, and in the cracks in the road from soil to plate. Regenerative agriculture has the capacity to address many of the challenges facing the current food system". - **Biome Capital**

Funding Mechanism		Key role	Current penetration In the agri-food sector in Ireland	Flexibility	Risk Tolerance
3	Investment	• Provision of resources to help set up companies and accelerate growth and scale Includes direct and Co-In-vestment in project / equity as well as yieldcos.	- Low Med - low	- Med -Low	- Med -high - High

- With the accelerated rates of land degradation, around 20-40% of the world's land area, according to the UN[182], regenerative agriculture is fast becoming a focus for investors.
- Investors are attracted by the sector's potential to boost food production, improve the livelihoods of those in the world's most vulnerable agricultural communities.

Farmland Investment Offers Strong Fundamentals

- Farmland investments are by far the largest asset class in the regenerative financing ecosystem (table 8. 2), representing almost half of assets under management in the USA.[183]
- The past 15 years, especially, the USA have seen a significant increase in farmland investing among private equity investors and institutions (Figure 8.4) driven by the recognition of strong fundamentals[184].
- In Ireland, the landscape is not dissimilar. "Demand for farmland to meet environmental objectives is one of the strongest drivers for growth" says Savills.[185] This is due in part due to changes to the agriculture and forestry policies, that have made it possible for investors to claim both CAP area-based payments and forestry payments on newly planted agricultural land. The country has also seen an increase in investment flows from big institutions from abroad to invest in Irish land with polarised reactions and raising concerns.[186]
- In the US, for the 30 years, farmland has been a stable value that appreciates over time[187]

	COUNT	ASSETS (Billions)
Cash and Cash Equivalents	5	$1.2
Fixed Income: Public Debt	3	$5.3
Fixed Income: Private Debt	17	$2.8
Public Equity	4	$8.4
Private Equity / Venture Capital	12	$6.9
Farmland / Real Assets	29	$22.8
Total	70	$47.5

Source: Croatan Institute.

Table 8.2: *Investable Strategies Identified with Regenerative Agricultural Features*

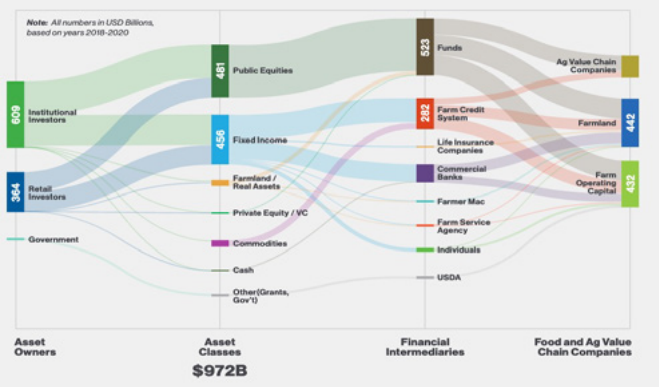


Figure 8.4: *Annual Agricultural Capital Flows in the*

182 Global Land Outlook – UN, April 2022 https://www.unccd.int/sites/default/files/2022-04/GLO2_SDM_low-res_0.pdf

183 https://croataninstitute.org/images/publications/soil-wealth-2019.pdf

184 Transformative Investment in Climate-Smart Agriculture Unlocking the potential of our soils to help the U.S. achieve a net-zero economy Feb 2021

185 https://www.savills.ie/blog/article/323989/rural-property/farmland-investment--as-safe-as-houses--but-with-better-returns.aspx - Jan 2022 -

186 https://www.irishtimes.com/environment/2023/01/20/coilltes-british-partner-attempts-to-soothe-fears-over-irish-forestry-deal/

187 USDA, TIAA Center for Farmland Research via SLM Partners

- Average farmland prices have continued to increase (figure 8.5). Two main exceptions in the past 50 years: the farm crisis of the 1980s and the recession of the 2000s.
- In Ireland, the average farmland values climbed 6.2 per cent in 2020, the strongest annual growth since 2014. This growth was led by grassland, with values for low grade livestock land and average quality livestock land increasing 8.8 per cent and 8.7 per cent respectively since December 2020.[188]

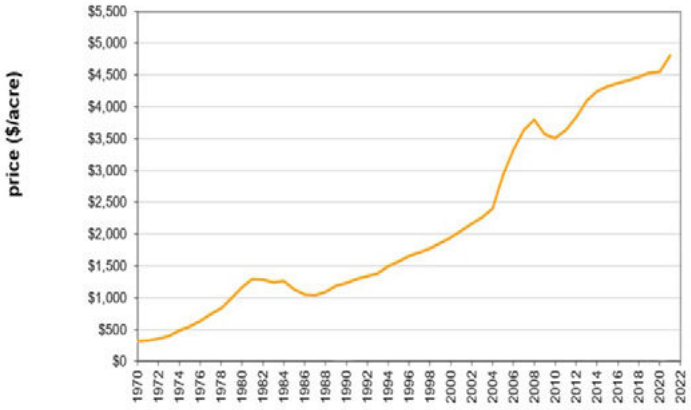
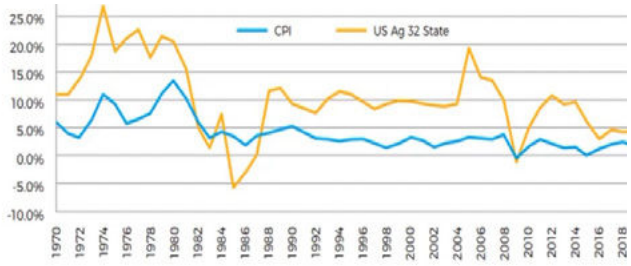


Figure 8.5: *Average Cropland Prices, US 1970 -*

Farmland provides a hedge against inflation:

- Food prices are closely linked to inflationary trends (figure 8.6). Because of this, owners of farmland assets and those exposed to agri-cultural businesses are likely to have a hedge against inflation.[189]
- In the period between 1970 to 2020, farm-land in the US shows strong returns and attractive risk return ratios.
- Farmland compares favourably to other asset classes, demonstrating strong returns per unit of risk, when measured on a risk-return basis.
- Agricultural land has outperformed both domestic stocks and bonds on an annualized basis over the last 48 years, providing both consistent income and capital appreciation.[190]



Decade	Farmland to CPI Spread
1970s	11.1%
1980s	1.0%
1990s	6.6%
2000s	7.6%
2010s	4.8%
1970 - 2020	**6.1%**

Figure 8.6: *US Farmland aggregated returns vs inflation 1970 - 2022*

- In Ireland farmland also compares favourably to other asset classes. Savills forecasts, for example have a total return of 8.8 per cent per annum for low grade livestock land, outperforming residential asset classes. Prime arable forecasts, at 5.6 per cent annualised total return is nearer to the bottom of the forecasts, maintaining its investment appeal as a safe and reliable asset.

188 https://www.savills.ie/blog/article/323989/rural-property/farmland-investment--as-safe-as-houses--but-with-better-returns.aspx - Jan 2022 -

189 Source: Bureau of Labor Statistics, TIAA Center for Farmland Research, Peoples Company via SLM Partners

190 U.S.-only NCREIF Farmland Index

Impact Investing

"Purpose is not the sole pursuit of profits but the animating force for achieving them – profits are in no way inconsistent with purpose". **Larry Fink, CEO of Blackrock.**

Impact investing has gained in popularity and momentum over the past decade, capturing the attention of the philanthropic and charity sectors. In general, impact-oriented investors see an opportunity to achieve financial returns while improving environmental, outcomes on the land and supporting farmer livelihoods.

Impact investing is a fast-growing source of capital funds[191] which could be attracted to regenerative and innovative Irish Agrifood projects. However, impact investment – as with any other type of capital alone - cannot fund a transformation of this magnitude on its own. There are many public and private organizations working to effectively put private capital to use for public good. Some are doing this more effectively than others, some, more authentically than others. Impact investment actors in the green-washing or green wishing space are not considered in this report.

Cienega Capital is a single-family office impact investment fund in the USA. Together with the Globe-trotter Foundation, they are investing in what they "The No Regrets Initiative."[192] For them, the collective vision is to regenerate agricultural soils and communities throughout North America." As of December 31, 2019, Cienega has invested over $13.5M, approximately distributed as 47% in working capital, land, and equipment loans, 17% in equity (including an organic seed company and grass-fed beef aggregator), 10% in like-minded funds, and 14% in a joint land venture with a rancher" Esther Park, CEO.

Within the UK Impact Investment sector there are 355 funds with investments in SDG2 – Zero Hunger and 451 funds with investments in climate action – SDG 13 (table 8.3). However, the total number of funds investment over 5% in the SDG remain relatively low.[193]

Table 8.3: *UK Investing in Relevant Agri-Food SDGs*

UK Impact Investment Funds	SDG2 - Zero Hunger	SDG3 - Good Health and Well-Being	SDG6 - Clean Water and Sanitation	SDG9 - Industry, Innovation andInfrastructure	SDG12 - Responsible Consumption and Productior	SDG13 - Climate Action
Total number of Funds with Investments in each SDG	355	438	439	453	453	451
Total number of Funds investing 5% plus in this SDG	10	82	31	271	137	130

191 GIIN

192 https://www.noregretsinitiative.com/category/cienega-capital/

193 B Corp's worldwide Directory of B Corps - January 2023

Information regarding regenerative impact investors in Ireland is not available. Most investment funds referenced as impact investors seem to prioritise software as the main area of focus. [194]

8.5 Funding the Agriculture Value Chain Transformation

"The world's dependence on nature is moving from something that is invisible and under-valued to one that is explicitly recognized, valued, and traded."

Key Intervention Point

Regenerative Agriculture - holistic management and higher returns in a reduced risk environment for Agri-food.

"The economic returns of restoring land and reducing degradation, greenhouse gas emissions and biodiversity loss could be as high as $US 125-140 trillion every year - up to 50% more than the $93 trillion global GDP in 2021."195

The intention of this section is to share some highlight the potential of the regenerative agri-food as a key intervention point, providing a key summary on regenerative agriculture, as well as the key economic drivers it addresses. We want to believe that regenerative agriculture is a key intervention point to fund the agri-food transformation in Ireland. We believe that the capital that can be deployed in regenerative agriculture could generate a multiplicity of changes, with positive results for people, nature, and the bottom line. Focusing on regenerative agriculture can also prepare the sector to effectively respond to the key 6 trends we highlighted at the beginning of the document.

Around 20-40% of the world's land area – including agricultural land, drylands, wetlands, forests and grasslands — has been degraded to some extent, affecting almost half the world's population. If current rates of deterioration persist, additional degradation by 2050 would cover an area nearly the size of South America, according to the United Nations[196]. The restoring capacity of regenerative farming and the avoided costs and losses drive healthier and better profits that conventional systems, according to different studies.

The funding community is looking closely at the regenerative production systems. The integrated economic, agronomic, environmental, consumer and climate benefits present a clearer perspective of the risk and profitability of the asset. Investing in regenerative agriculture can be significantly more

194 https://shizune.co/investors/impact-investors-ireland

195 UN Global Land Outlook 2

196 Global Land Outlook – April 2022
https://www.unccd.int/sites/default/files/2022-04/GLO2_SDM_low-res_0.pdf

profitable than conventional agriculture. The system of practices can lead to lower input costs, the ability to grow higher value crops and access new markets and premiums. An additional benefit is the increased resilience, reducing risks associated with volatile weather.

To unlock the acceleration of the urgent transition to regenerative agri-food for the highest good of the people and the planet requires:

- A tailored and integrated system's approach that responds to the real needs of the land and the value chain actors
- A systematic process that independently identifies and mitigates value chain risks through an integrated risk-based performance management approach. This includes among other procurement risks, environmental risks, knowledge risks and funding risks.
- Authentic, independent identification and prioritisation of real needs of the value chain rather than the individual "wants"
- A clear identification, curation, and consistent management of the data.
- A systematic approach, that builds strong and trusted relationships with the different actors in the value chain.

Regenerative agri-food can become a new asset class. Degraded land globally could expand by area the size of South America by 2050. To quote Legrix de la Salle, "We will put money into some projects where the farmers will be trained, we could finance equipment, and there will also be some finance to protect their revenue over the transition."

- Aligning financial flows with national action represents an immediate opportunity to align targets and commitments to implement land restoration, realise multiple benefits, and maximise returns on investment
- Investments in regenerative agri-food, when managed correctly offer healthy returns and numerous other ecological, economic, and social benefits.
- Many traditional and modern regenerative food production practices can enable agriculture to pivot from being the primary cause of degradation to the principal catalyst for land and soil restoration[197]
- Restoring land, soils, forests, and other ecosystems would contribute more than one-third of the cost-effective climate change mitigation needed to limit global warming to 1.5°C while supporting biodiversity conservation, poverty reduction, human health and other key sustainable development goals.

197 Carbon: 1% increase in soil organic matter due to holistic management results in 7.2tC/ca*.

*SOM is approximately 58% organic carbon; 1% increase in SOM/ha = 0.58% increase in C/ha; At a bulk density of 1.2 g/cm3 (equivalent to 1.2 tonnes/m3), a 0.58% increase in C/ha to a depth of 10cm would give 7.2 tC/ha... so 1% SOM/ha = 7.2 tC/ha. (math: Western Australian govt). Other sources seem to give a round number of 8 tC/ha, just FYI; 44 units CO2/12 units C (source: EPA)... so 1% SOM/ha = 26.4 tCO2/ha = 7.2 tC/ha

Water: "Each 1 percent increase in soil organic matter helps soil hold 20,000 gallons more water per acre." (source: NRDC). Using a bulk density of 1.33 g/cm3 they give an exact storage of 21,668 gallons of water to a depth of 6"; 1.2 g/cm3 bulk density from the carbon calculation, going to the same depth, and converting to hectares, a 1% SOM increase = 31,700 gallons (120,000 kg) H2O per hectare; same per 1 ton of C/ha 1% SOM/ha = 31,700 gallons H2O/ha = 7.2 tC/ha; 1 tC/ha = 4402 gallons H2O

Early transition risks are to be considered. Even if regenerative can lead to better economic outcomes, there are still initial risks during the process of the change, when transition costs – both human and financial – are highest, and premiums are not yet attainable. Additional barriers to transition include the challenge of behaviour and cultural change, a lack of trusted technical assistance, inadequate regenerative supply chains, and the need for financial capital and incentives to take on the risk. These barriers can be significant, but diverse forms of capital can play a role in addressing them.

Economic drivers

One of the biggest misconceptions about regenerative agriculture is the assumption that regenerative agriculture leads to lower yields and therefore may not be as profitable. Profitability and confidence level risks can be mitigated by two main factors: input costs and market demand. Regenerative agriculture has the potential to be considerably more profitable than conventional agriculture.

- Lower input costs: Farmers are operating on thin margins – low commodity prices, combined with high input costs[198].
  - The Covid and Ukraine Shocks have had a direct impact on the need to account for the true cost of supplies in the value chain, and it is becoming a priority for leaders.
  - Traditional cost models are being re-evaluated and the 'True Cost of Low Cost' is a nascent movement within the procurement world. And eing used as an adoption methodology for organisation like Project X.
  - Adequately implemented regenerative practices can lead to lower input costs.
  - Volatility of input costs has and will continue to have an impact on breakeven levels[199].
- Higher value outputs: the second driver of profitability in regenerative agriculture – new markets and access to premiums – comes from the ability to diversify into higher value outputs that can be marketed at a premium. This effect might be temporary as the sector is moving towards making regeneration the new normal. It will probably take more time than we hope for, but it is on its way and here to stay.
- Increased resilience, reducing risks associated with volatile weather.

Risks and yields. There are a good number of credible research studies seeking to understand the connection between yields and profitability in regenerative agriculture. Jonathan Lundgren of Ecdysis Foundation and Claire LaCann[200] found that the farms with regenerative practices were 78% more

198 DTN Fertilizer Index, a weekly survey of U.S. retailers

199 Two reports published in 9 months show contrasting data on the price performance of fertilizer. Although historically fertilizer prices have continued to rise (DTN report published March 30, 2022) a recent article in Perdue Agribusiness published in December 2022 demonstrated a new trend in pricing.

200 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5831153/

profitable than conventional plots. Rodale Institute[201], for example, has been running field studies for the last 30 years comparing organic and conventional agriculture. The American Farmland Trust identified a clear correlation between key regenerative practices and the decrease or increase in costs and income.[202]

Breakeven Point. A recent Bain and Nature United study[203] concluded that initial yields will be lower while beginning the process of changing farming techniques, leading to less marketable produce and less profit, until a farmer would break even in year 4, and make the same amount they would have before transitioning to regenerative practices. Other studies estimated breakeven could be achieved between 2 to 3 years. Funders are becoming more comfortable with the monetization value of regeneration. Returns from investment in farmland come from both capital appreciation and from current income from the farm, which according to SLM Partners, in many ways serves to double the capital appreciation.

Vulnerabilities and Inherent funding mobilization risks of the traditional agri-food system

- Investment in conventional or industrial farmland, comes with unique risks. These risks are mainly associated with the chemically intensive way farmland has been managed for the past 50+ years, which degrades the asset itself.
- U.S. farmland income in the past 3 years the income as a percentage of land value has settled at an average of 3% creating a commercial risk for the average farmer.[204] "This is financially suffocating farmers, making it more difficult for average farmer to compete in current economy, let alone invest back into their operation".
- To grow income, farmers need to (i) get bigger so they can produce more or (ii) find other ways to build more income on their existing farms, with associated risks.
- Regenerative Farming offers a way out of the continuous spiral of scaling up to a more cost-efficient model.

201 https://rodaleinstitute.org/why-organic/organic-basics/regenerative-organic-agriculture/
202 https://farmland.org
203 https://qz.com/2093871/regenerative-farming-can-reduce-emissions-and-be-more-profitable
204 USDA, TIAA Center for Farmland Research via SLM Partners

8.6 Collaborative Capital: The Way Forward

Complex ecosystems cannot be addressed with linear solutions. Integrated 'systems funding' mechanisms will be imperative to solve this at the pace the planet needs it. "We've been coasting along for more than half a century in unprecedented affluence, unprecedented freedom, unprecedented optimism. And all of a sudden, we are facing the fragility and vulnerability of the human situation." Rabbi Jonathan Sacks.

The intention of this section is to highlight the value of collaborative capital as the way forward to accelerate the mobilisation of funds at the scale and pace required in the agri-food sector, especially during times of fragility and vulnerability. 'The economy, business and society don't sit apart from nature, but within it'. To progress with the potential that regenerative agriculture brings in mitigating climate change, improving soil health, and building community resilience, a systems approach that recognises this is required.

- An orchestrated approach that moves away from the 'solo funder' model
- An ecosystem of capital collaborators to de-risk the proposition of investment at scale, reducing the risk for all participants.
- A way to address the funding gap by bringing key funders together to fund key leverage points where funding is more needed.

The size of the financing gap.

The size of the financing gap is seen by many as an academic exercise. It is worth, however considering relevant studies to have an understanding of the size of this gap and the potential to leverage collaborative instruments. The Climate Policy Initiative for example, shows the significant size of the climate finance necessary to maintain the 1.5 pathway (figure 8.7). In their report published in November 2022[205] they emphasised the need for new capital.

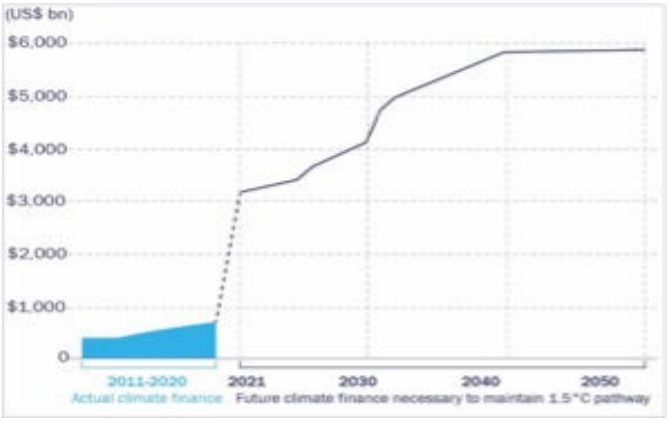


Figure 8.7: *Climate Finance forecast 2050 – Climate Policy Initiative*

205 https://www.climatepolicyinitiative.org/wp-content/uploads/2022/11/Landscape-of-Climate-Finance-for-Agriculture-Forestry-Other-Land-Uses-and-Fisheries.pdf

Given the significant size of the estimated gap, it is not difficult to see how it can exceed the capacity of the public or the private sector alone. Under a stretch scenario, private funds will have to account by 2025 for US$430 billion of the $780 billion in additional annual financing in developing countries alone (excluding China) (figure 8.8), as reported by LSE Grantham Research Institute and Rockefeller Foundation in 2021. Linking public and private initiatives and working in a joined-up manner, harnessing private finance and the critical role of governments to address the capital requirements is fundamental. "Governments need to play an essential role by repurposing existing harmful public support for unsustainable AFOLU[206] towards sustainable agricultural production practices and healthy diets" [207]

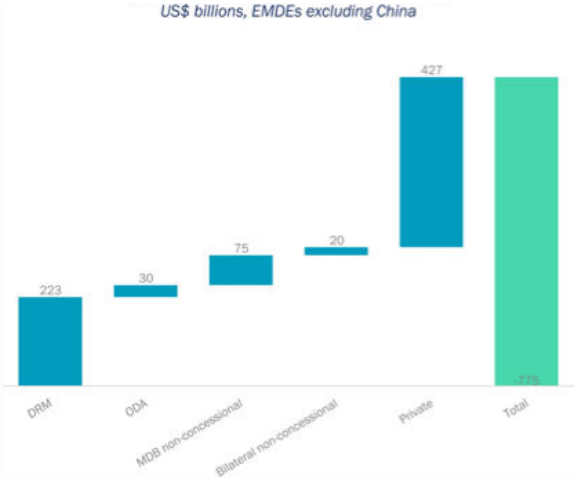


Figure 8.8: *Incremental Financing Needs 2025 LSE Grantham Research Institute and Rockefeller Foundation, 2021*

Key collaborative and Innovative funding instruments

"Utilizing an integrated capital approach to systemic change in the areas of soil health, regenerative agriculture, and local food systems." Cienega Capital

In this section we will look at key examples of collaborative funding models. Collaborative models can help organisations safely operate and thrive in a world where shocks are the new norm. They are useful to move from individually tailored deals to portfolio-level approaches that can:

- Funding complex structures via hybrid and or blended models
- Blending skills, knowledge and experience
- Minimising risk, cost and process-heavy fragmentation unlocking right risk and size assets for key volume investors
- Increasing mobilisation ratios
- Welcoming rapid replication and scaling
- Structuring robust governance frameworks that would help ensure the funding models achieve value for money, and impact, providing comfort to key stakeholders.
- Bringing additionality against benchmarks for impact
- Generating better data and better transparency

206 AFOLU – Agriculture, Forestry, Other Land Uses and Fisheries

207 https://www.climatepolicyinitiative.org/publication/landscape-of-climate-finance-for-agriculture-forestry-other-land-uses-and-fisheries/

We prioritised key collaborative funding models based on their relevance to the agri-food sector, their flexibility and risk tolerance. These include, development funding, transition finance, catalytic funding, and regenerative finance.

Development Funding

Development funding is a key funding mechanism in the agri-food space. It is typically used to support small scale borrowers or investments with high impact in terms of social inclusion or environmental sustainability. The instrument can also facilitate credit risk sharing or transfer between commercial financial institutions, and development and philanthropy actors. Some relevant examples on development finance (including blended finance models) in the agri-food space can be found in Safine Network.[208]

According to OECD "Governments have the financial instruments to mobilise private finance for agri-SMEs, via their aid agencies, or development finance institutions (DFIs) or multilateral development banks (MDBs). Now it is important that they act upon it". [209]

- EU countries have committed to spend 30% of the EU's long-term budget for 2021-27 and Next Generation EU for climate-related projects. The EU has introduced a just transition mechanism which aims to provide financial and technical support to the regions most affected by the move towards a low-carbon economy. Up to €90 billion is to be mobilised to this end.
- A mix of private funding and state Aid in Ireland in the form of grants mainly, is growing in importance as a source of financing the local economy. The Woodland Environmental Fund (WEF), for example is encouraging the planting of more native woodlands within Ireland by providing an access point for businesses to part fund the establishment of these forests.[210]
- The Irish Government provides different schemes to support local farmers[211]. Under the Targeted Agricultural Modernisation Scheme (TAMS II) payments have exceed €360 million to date. Schemes include among other the Dairy Equipment Scheme, the Organic Capital Investment Scheme, Pig and Poultry Investment scheme, Tillage Capital Investment Scheme and Low emissions scheme.[212]

208 https://www.safinetwork.org/safinresources/Blended-finance-for-agriculture

209 OECD 2021 - Making Blended finance work for Agri-SMEs 2021

210 Woodland Environmental Fund - Department of Agriculture, Food and the Marine. 16 November 2020. Last updated on 22 December 2021. https://www.gov.ie/en/service/b2a2b-woodland-environmental-fund/

211 Department of Agriculture, Food and the Marine. Last updated on 6 September 2022 - Government Agriculture Modernisation schemes

212 https://www.gov.ie/en/service/targeted-agriculture-modernisation-schemes/
https://www.gov.ie/en/service/90794e-young-farmers-capital-investment-scheme/
https://www.gov.ie/en/service/a0e075-dairy-equipment-scheme/
https://www.gov.ie/en/publication/24875-terms-and-conditions-of-the-organic-capital-investment-scheme-ocis/
https://www.gov.ie/en/service/d4b800-low-emission-slurry-spreading-less-equipment-scheme/
https://www.gov.ie/en/service/406a9b-pig-and-poultry-investment-scheme/
https://www.gov.ie/en/service/43e846-animal-welfare-safety-and-nutrient-storage-scheme/
https://www.gov.ie/en/service/fb5ed7-tillage-capital-investment-scheme/
https://www.gov.ie/en/collection/65f5b-tams-farm-building-and-structures-specifications/

Transition Finance

Transition Finance has been generally understood as "being intended to decarbonise entities or economic activities that: (i) are emissions-intensive, (ii) may not currently have a low- or zero-emission substitute that is economically available or credible in all relevant contexts, but (iii) are important for future socio-economic development". ICMA[213] considers that 'transition bonds' can be either green, sustainability bonds or sustainability-linked bonds issued by entities looking to align their financing strategy to their climate transition strategy and decarbonisation journey. Conversely, CBI[214] proposes a 'transition' label and defines transition bonds as use-of-proceeds instruments used to finance activities or entities that are not low- or zero-emission (i.e., not green), but have a short- or long-term role to play in decarbonising an activity or supporting an issuer in its transition to Paris Agreement alignment. Market actors, according to the OECD Survey, consider that debt-related instruments will be deployed over equity in transition finance-related transactions[215] (figure 8.9).

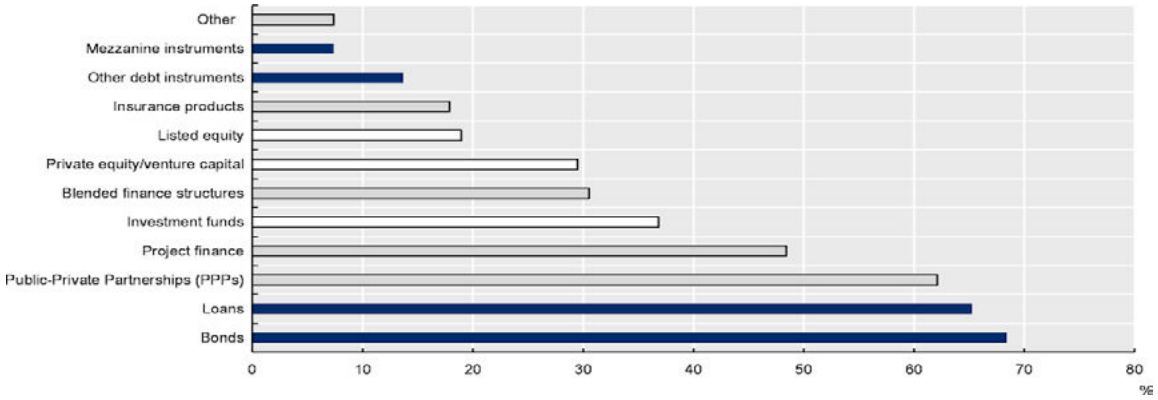


Figure 8. 9: *Market actors consider that debt-related instruments will be deployed over equity in transition finance-related transactions*

Note: *Survey Question: Which financial instruments or mechanisms will be most deployed for transition finance-related transitions, in your view? The number of respondents (Market Actors[216]) for this survey question was 95.*

Catalytic Funding

Catalytic funding is a form of blended finance. It is patient, flexible, risk-tolerant financing. It respects the 'self interest' of the different funders, to invest alongside each other while achieving their own objectives (financial return, environmental or social impact, or both). Organisations like The MacAr-

213 ICMA (2022), Guidance Handbook, https://www.icmagroup.org/assets/GreenSocialSustainabilityDb/The-GRP-Guidance-Handbook-January-2022.pdf

214 CBI (2022), Sustainable Debt, Global State of the Market 2021, https://www.climatebonds.net/files/reports/cbi_global_sotm_2021_02f.pdf.

215 2022 OECD Industry Survey on Transition Finance - https://www.oecd-ilibrary.org/sites/7c68a1ee-en/1/3/2/index.html?itemId=/content/publication/7c68a1ee-en&_csp_=de7026e6bbb9a2098a2b3b13291bc473&itemIGO=oecd&itemContentType=book#section-d1e3019

216 Market Actors include: financial institutions, non-financial corporates, academia, data and service providers, public finance institutions (such as central banks and development banks), and nongovernmental organisations and other relevant actors.

thur Foundation has been experimenting with this type of blended structures for some time with very positive results. To quote Debra Schwartz, The John D. and Catherine T. MacArthur Foundation. "Thirty years ago, we supported pioneers in microcredit and bolstered the once-fledgling field of U.S. Community Development Financial Institutions. Decades later, investments we made helped pave the way for others, marshalling billions of dollars for the benefit of low-wealth, underserved people across the US and around the world through loans, investments and financial services".

Regenerative Finance

Mostly a blended capital structure rooted in the theories of regenerative economics[217], this form of finance encourages individuals to generate an income by working on and funding public good projects. "The Innovation, entrepreneurship, and capacities are important, but they need to be linked by common-cause values, supported by commonwealth infrastructure, and nourished by cross-scale circulation of money, information, and resources." [218] As in any approach it has its fans and detractors, however this a system that rewards those who use their money as a tool to solve systemic problems and regenerate communities and natural environments, is a big improvement. Innovation in this space continues to evolve: ReFi is the regenerative finance movement forming at the intersection of the third evolution of the internet (Web3). A space to watch with great interest since it has the potential to significantly increase transparency and rate of adoption of regenerative agri-food practices around the world.

Green bonds and sustainability-linked loans

Green and sustainability-linked bonds are becoming a popular way of financing sustainability projects that deliver environmental benefits. According to the OECD, the market continues to grow with a global total sustainable debt issuance in 2021 accounted for USD 1.6 Trillion. Green bonds and sustainability-linked loans form 64% of the total (figure 8.10).[219] Bonds have the potential to provide long-term sources of debt capital adequate for land regeneration projects, and can allow for "recycling" of loans. Bonds can also access global and diverse pools of capital. Investor demand for green bonds continues to grow as ESG criteria become increasingly important.

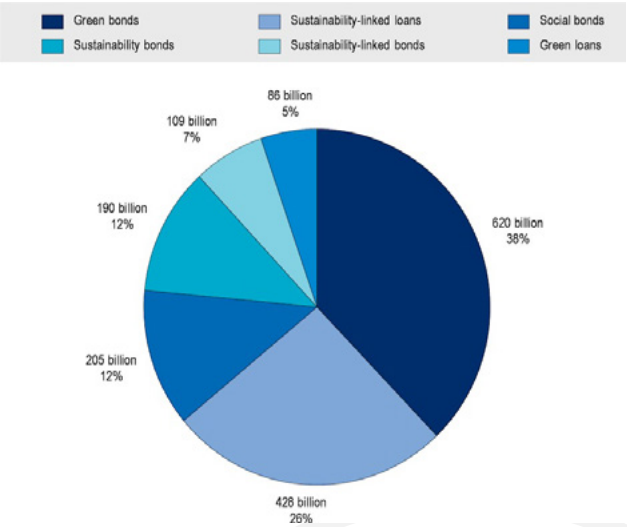


Figure 8.10: *OECD - Sustainable Debt Market by Instrument (2021)*

217 https://reallyregenerative.org/regenerative-economics/
218 https://www.sciencedirect.com/science/article/pii/S2589791819300040#fig3
219 https://www.oecd-ilibrary.org/sites/b0d62d2b-en/index.html?itemId=/content/component/b0d62d2b-en

To quote Michael R. Bloomberg, United Nations Secretary-General's Special Envoy for Cities and Climate Change, *"Financial markets can help solve the climate challenge by meeting the growing demand for low- carbon projects around the world. New financial tools like green bonds are helping drive more capital to these projects".*

Transition bonds

A growing number on entities are looking closely to originate notes whereby the proceeds will fund the financing of projects with clear environmental benefits. Recognising the importance of climate finance in funding the transition to a sustainable economy, transition bonds are increasingly used to finance sustainable solutions. It is estimated that they could total $1trn annually in the future. AIB, one of the largest banks in Ireland serving c 2.8 m customers, is walking the talk in their commitment to a sustainable future. Over the last two years, AIB has raised €3.25 billion from the issuance of green bonds after becoming the first Irish bank to issue a green bond in 2020. Also in May 2022, AIB raised €1 billion through the issuance of a social bond, the first social bond issued by an Irish bank[220]. An emerging concern with these instruments is that transition bonds could lead to 'transition washing'.

Collaborative instruments are diverse in nature and have specific objectives, from minimising the set up of a project set to fund growth and accelerate scale. There are interesting instruments (table 4), that could be leveraged to fund key regenerative agri-food requirements, at the right time.

Table 8.4: *Key Financial Instruments that could be leveraged to fund Regenerative agri-food*

Instruments	Main Objective	Key features	Main Leverage Point Ideal for
Blended Finance	Increase private sector investment in sustainable development, leveraging catalytic capital from public or philanthropic sources	• Philanthropic funding • Development funding • Private capital • Guarantees • Projects (or entities) that generate revenues to repay funders (not used to mobilise funding to projects without 'reasonable possibility of bankability') • Governance	Project Set Up Demonstration Stages Transition Scale
Catalytic Funding	Mitigating risk providing a lower-cost layer of capital	• "Blended pool," • Anchor • Debt instruments • Guarantees • Impact funds / Other private capital • high-impact intermediary • Diverse investor type • Governance • Measurement and verification	Project Set up Demonstration Stages Transition
Project Bonds	Provide long-term sources of lower cost debt capital adequate for land regeneration projects	• Debt Instrument • Performance Contracts • Technical assistance • Diverse investor type • Governance • Measurement and Verification	Transition Scale

220 AIB Nov 2022 - https://aib.ie/content/dam/aib/group/Docs/Press%20Releases/2022/AIB-green-bond-Issuance-november.pdf

Instruments	Main Objective	Key features	Main Leverage Point Ideal for
Guarantees and First Loss structures	Minimising risk for professional investors with guarantees and first loss structures to invest in higher risk assets	• First-loss tranche • Enabling institutional investment money • Diverse parties involved • Reference reference to the underlying contract • Measurement and verification	Sep tup Transition
Revenue Participation Mezzanine Capital	Defined target return for the investors while allowing the company to develop business without initially paying too much for the capital.	• Debt instrument • No loss participation mezzanine capital • Fix interest rate and a percentage of the revenues for investors • Impact incentives are integrated in the instrument	Set up Transition
Profit participation Mezzanine Capital	Defined target return for the investors while allowing the company to develop business without initially paying too much for the capital.	• No loss participation mezzanine capital • Fix interest rate and a percentage of profits (EBIT) • Impact incentives are integrated in the instrument	Set up Transition
Regenerative Finance (ReFi)	Articulate a complex systems solution applying nature's principles of regeneration to socio-economic systems	• Diverse Money instruments • Internet Web 3.0 Technology • Technical assistance • Governance • Measurement and verification	Set up Transition Scale
Structural Hybrid Funding: Equity Donation + Impact Investment	Increase the non for profit capital component and enables it to hand over capital to the second entity of the structural hybrid enterprise: a for-profit subsidiary.	• Philanthropic funding and commercial funding to fund "structural hybrids" (non for profit and for profit set ups) • Philanthropic capital (for the non for profit entity) • Impact / Commercial capital (for the for profit entity) • Hybrid features – eg revenue or profit participation (for the profit entity) • Impact incentives • Governance • Measurement and Verification	Set up Transition Scale
Structural Hybrid Crowd Impact Investment	Flexible funding structure	• Crowd investment - funds the non-profit entity via donations, or the profit entity via investments • Impact investment • Impact incentives	Set up
Transition Finance	Finance the speed up of the regenerative transition	• Financial instruments commonly associated with transition finance are: • sustainability-linked bonds • loans, and • transition bonds	Transition
Philanthropic loans	Bridge capital / patient capital	• Loan • No return earned • Return effectively donated back to the charity	Set up Transition
Venture Philanthropy	Bridge the impact investment gap	• Loans • Grants • advisory support from donors	Set up Transition
Yieldcos	Provide financing for large transformation projects, helping to reduce the cost of capital by broadening the investor base and improving liquidity..	• New Set up – new co • Equity – niche equity • Diversified equity allocations in institutional and retail investor portfolios • Long term contract • Project linked revenues • Performance contracts • Purchase agreements	Set Up Transition

8.7 The leverage role of procurement

"There is no impact without scale, there is no scale without procurement"[221]

In this section we will focus on the opportunity that procurement procuring differently offers for the Irish agri-food sector. Harnessing government and industrial purchasing power is critical to scale the production, procurement and consumption of regenerative agri-food at the pace the planet and the people in the planet needs it. As Carla Thompson Payton, Vice President for Programme Strategy – W.K. Kellogg Foundation puts it, *"Procurement is a powerful tool that can transform our food and farming systems"*.

The critical confluence of corporate interest, collective wisdom and consciousness of people who care about the health of the people and the earth are critical building blocks of the funding ecosystem in the agri-food space. To escape tradition and provide future proof funding, embracing 'Consciousness Procurement' is a rising priority. This is about enhancing the act of buying (value chain supplies) with high levels of understanding, appreciation and respect of people and nature. Quality, cost, and speed will of course continue to be critical criteria.

Innovative hybrid models like the Potlikker - a charitable loan fund in the USA, takes an integrated capital approach to deploying reparative capital using a combination of non-extractive investments, zero and low interest loans, and grants and recoverable grants. "The fund will support climate-friendly agriculture and healthy food by increasing the role of community organizations in 'good food procurement' which aims to shift billions of food purchasing dollars spent by schools, hospitals, and other institutions to nourishing, sustainable, local and equitably sourced food". [222]

Axa, Tikehau Capital and Unilever have joined forces to launch a new regenerative agriculture fund. The €1 billion reflects investor appetite for regenerative agriculture, and hopes to play a major role in tackling both land degradation and climate change[223]. The unique partnership reflects the value of bringing closer global buyers into the operational investment space.

221 Project X Global - https://projectxglobal.com

222 The Rockefeller Foundation – 3 Oct 2022. https://www.rockefellerfoundation.org/news/the-rockefeller-foundation-announces-over-10-million-to-increase-equitable-and-sustainable-food-procurement-practices-across-the-u-s/

223 https://www.unilever.com/news/press-and-media/press-releases/2022/regenerative-agriculture-transition-to-be-accelerated-through-new-impact-fund/

8.8 Carbon

From speculative to core in the regenerative agri-food space.

> **"If we find a way to not only gain access to added values for the raw material created by the producers, but also be able to find the mechanism for these producers to be "rewarded" for producing regeneratively (whether through an ecosystem credit or through the exclusion of interest rates or low interest rates), the short, medium and long term for the producers is promising". Producer.**

This section focuses on Carbon as a mechanism to generate additional income and capital flows to the farmers.

GHG emissions in the agri-food system. Of the 16.5 billion tons of GHG emissions from global total agri-food systems in 2019, 7.2 billion tons came from within the farm gate, 3.5 from land use change, and 5.8 billion from supply-chain processes, according to the UN Agricultural Agency analysis. To mitigate some of the damage, various carbon trading schemes have been created. These schemes allow companies to offset their emissions by investing in projects that remove or avoid carbon from the atmosphere. The main issue currently facing carbon schemes is the lack of transparency often associated with corruption.

True demonstrable and verifiable carbon credits (units/claims), and by this we do not mean smoke credits, can offer a tangible solution to farmers implementing sound regenerative practices. This could help maximise value of the assets for the producer, increase the currently low rate of carbon retirement and mobilise additional funding, and guarantees to the sector. "More flows of capital could make the transition to regenerative easier and faster, generating greater productivity and improving income per producer".

Demand of 'issuable credits' far outstripping supply. The inventory of voluntary carbon credits fell by around 50% between January and December 2021 as reported by Sylvera[224], despite the significant growth in demand, due mainly to the increased interest from buyers with ambitious net zero commitments. This situation does not seem to get better in the short terms due mainly to three key issues: (i) Lack of credible and reputable programmes, (ii) the natural time carbon credits take to come to market – e.g 3 to 5 years, and is some cases 7 years according to experts, and (iii) the serious concerns about dodgy schemes and fraud with added costs, compliance and reputational implications for the market.

224 https://fs.hubspotusercontent00.net/hubfs/7608351/2022%20Carbon%20Credit%20Crunch%20Report%20.pdf

We are *at portas* of a high-quality carbon credits supply crunch that must be addressed if the VCM is to scale to the level required to tackle the triple crisis of climate change, biodiversity loss and desertification/water stress.

Time to rethink the incentives. *"Net zero forces the carbon market to grow up too fast".* Despite the good intentions behind the $12bn Governments pledge to protect and restore forests, the increasing pressure from corporates and government and the questionable methodologies behind carbon credits, are creating serious problems in the carbon credits market. Several carbon credit projects have received significant negative media attention and the public is asking whether the Voluntary Carbon Markets - VCM is simply enabling companies to buy false environmental credibility. New investigation from the Guardian published January 2023[225] challenged the validity of forest carbon offsets approved the world's leading provider. The investigation claims that "more than 90% of rainforest carbon offsets by biggest provider are worthless". There are however reputable nature-based carbon projects that can help address climate change, nature restoration and conservation and community health that need finance.

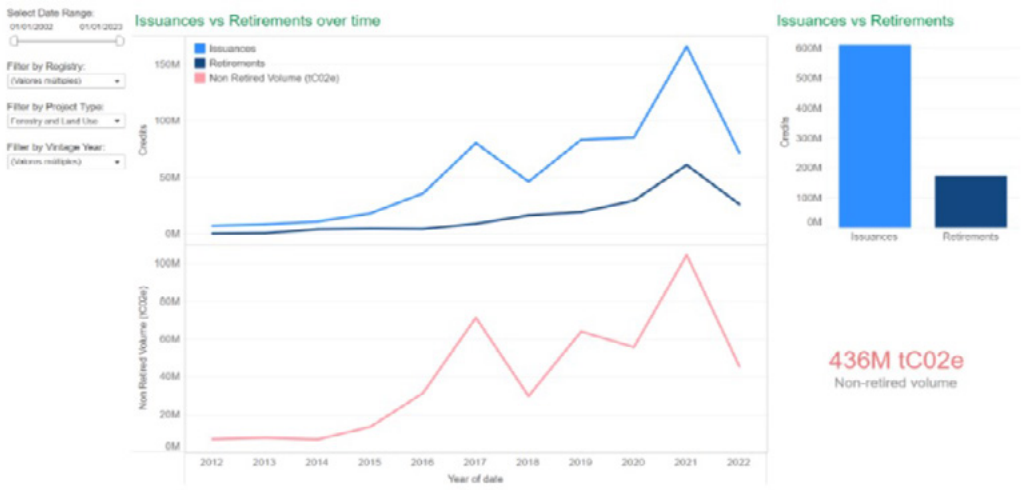


Figure 8.11 : *Issuance vs retirement rates is driving the demand and boom for high-quality credits.*

Carbon credits are failing to deliver value back to the land. Carbon retirement levels remain low. An estimated 609 million forestry and land use carbon credits (corresponding to one Mt CO_2e each) have been issued since the start of 2012. (Allied Offsets. This number covers the following registries: ACORN, ACR, CAR, Gold Standard, NORI, Puro.earth, and Verra.) 173 million of these have been retired - leaving a non-retired volume of 436 million credits (figure 8.11). A significant proportion of these non-retired credits are likely held by resellers and brokers – estimated market of $1.331bn, waiting for the price to increase.

225 Revealed: more than 90% of rainforest carbon offsets by biggest provider are worthless, analysis shows | Carbon offsetting | The Guardian

Table 8. 5: *Average price of carbon in market per ton*[226]

CarbonCredits.com Live Carbon Prices	Last	Change	TD
Compliance Markets			
European Union	€76.40	+3.20 %	–4.76 %
California	$28.99	-	–9.46 %
Australia (AUD)	$32.50	-	–36.27 %
New Zealand (NZD)	$87.85	–0.17 %	+28.34 %
South Korea	$12.71	+0.59 %	–48.01 %
China	$8.06	–0.34 %	+6.60 %
Voluntary Markets			
Aviation Industry Offset	$3.06	–4.38 %	–61.75 %
Nature Based Offset	$5.49	-	–61.01 %

Nature Credits. Beyond Carbon - Ecosystem Services. The World Economic Forum (WEF) recently published a report[227] outlining the opportunity to grow the biodiversity credits market. Noting that, "En route to adopting regenerative business practices, there is an opportunity to protect critical ecosystems that businesses and the world depend on from irreversible tipping points," through the purchase of biodiversity or nature credits. The WEF suggests that purchasing these credits should be a step on a company's 'nature-positive journey,' acting as an investment in nature's recovery, rather than an offset for damage. A separate asset class could also make it easier for companies to invest in nature-positive projects that relate more closely to their supply chains. There is a considerable variation however, on the average price of carbon, between regions and between the compliance and the voluntary market (table 8.5).

8.9 The five order challenges

"The universal patterns and principles the cosmos uses to build stable, healthy, and sustainable systems throughout the real world can and must be used as a model for economic-system design". John Fullerton

In this section we will focus on the less obvious but potentially far more powerful key places to intervene in the agri-food regeneration system. We call these the five order challenges. There is increasing innovation going into designing financial vehicles that address the barriers to regenerative adoption – including risk, capital, technical assistance and innovation. However, and despite substantial focus on unlocking funding to address the key challenge of regeneration, funding remains largely unattainable or remains in the 'not enough, not on time' category. New instruments created to protect the land, have ended massively deviating from the true intention, creating parallel smoke markets where just the very few get rewarded, and the land and her stewards keep struggling. Partly, this is due to the failure

226 carboncredits.com 23 November 2022

227 WEF - Biodiversity Credits: Unlocking Financial Markets for Nature-Positive Outcomes. September 2022 https://www3.weforum.org/docs/WEF_Biodiversity_Credit_Market_2022.pdf

of funding to engage with the root causes of regeneration and the relevant interconnectivities of the system. Although we acknowledge that many funding interventions are tangible, they are essentially weak leverage points (i.e. using interventions that are easy, but have limited potential for transformational change).

1. **Funding the value chain transformation main risk is a technical risk rather than a market risk. This is the first order challenge.** Funders, mainly institutional investors and financial institutions and companies don't have a structured or auditable way to invest in nature. Funders still don't know if their money will be used wisely and regeneration will actually happen. This is an implementation risk, termed 'technical risk'. There is money in the system. Investing in healing the land and harvest its abundance with respect, supported by trusted technical assistance on the ground to effectively transition to regenerative practices[228], makes business and planetary sense.
2. **The second order challenge is the systems's interconnected risk**, particularly during a transition period. This is a key barrier to adoption of regenerative techniques. Understanding interconnected risks (the so-called unintended consequences) specifically, during the initial process of the change, when transition costs are highest, premiums are not yet attainable and additional income flows – eg carbon, with the potential to strengthen the repayment structure, is critically important to reduce the risk for all participants and contributing to the allocation of the right capital and the right time.
3. **The third order challenge is adoption.** Although there is an increasing demand for regenerative agri-food products, there is not yet a homogenous response from the buyers to pay premiums for regenerative inputs. Buyers are being pressured to deliver on their net zero commitments. It is nothing but expected that if there is an 'easy route' to achieve net zero, it will be taken. Focusing on helping buyers accelerate the uptake of regenerative inputs into their value chain is a core point of leverage.
4. **The fourth order challenge is rhythm.** the mismatch between the financial and the natural rhythms. The positive ecological and financial returns of regeneration decisions are often unrealized or insignificant until the end of the loan / lease term when they were made. The loans or lease tenors (often less than three years) can discourage farmer investment in the transition to organic or other practices.
5. **The firth order challenge is identity.** To effectively transform a system, a system identity, with its own culture and language is key. Addressing key language and cultural gaps in key asset classes and funder types, and leveraging transparency and technological innovation to support this, has a significant potential for transformational change, promote a common understanding of regeneration financing and related risks as well as addressing risk perception and confidence levels.

228 https://savory.global is an example of tangible execution of regenerative practices on the ground, with over c 15 million hectares influenced globally and over 14,100 farm managers trained since 2009.

8.10 Summary & Key Conclusions

Below is the summary of key findings from our contextual analysis:

A systems' approach is not a nice to have but a fundamental requirement when funding a transformation of this magnitude. Funding at the pace and scale that the agri-food system requires will continue to fail without a holistic view of the system, with a clear understanding of key leverage points, interconnected risks, and value generation.

Regenerative agriculture is a key intervention point and a guiding red thread to succeed in funding the agri-food funding ecosystem. It addresses key agri-food economic drivers such as input costs and market demand, as well as environmental, biodiversity and social drivers, under one umbrella.

Current carbon models and incentives are slipping away from the original true intention to preserve our planet. Percentages of carbon retiring on the ground remain low; income flow for farmers is not increasing; regenerative practices cannot be sustained or funded due to low margins. Opportunities to maximise the assets of the land linked to true regeneration are emerging creating a tangible opportunity to disrupt the smoke credits market.

A diverse group of funders are becoming more and more aware of the monetization value of regeneration. Confidence levels in the ability to technically transition to true regeneration is still low, delaying the flow of existing, and vast, flows of capital to the regeneration agri-food sector.

Collaborative capital is the way forward. Collaborative funding models enable the provision of funds in key intervention points at the right time, and help minimise the risk for the participants, when adequately structured. Flows of funds are available but allocations in regenerative agri-food remain still low, vis a vis total funds allocated to agriculture and other key sectors of the economy. New mission aligned entrants as well as blended structure participants have a golden opportunity to accelerate the allocation of strategic funds for the mobilisation of additional private finance towards regenerative agri-food.

Covid, and the war in Ukraine, like many other shocks before them, have exposed the agri-food industries to critical dependencies, exposing vulnerabilities in entire value chains. Funders are becoming more aware of the intrinsic risks of the so-called externalities and the direct correlation with leverage and returns. The need to account for the true cost of supplies in a value chain is becoming a priority for funders. Traditional cost models are being re-evaluated and the 'True Cost of Low Cost' is a nascent movement within the procurement world.

Growing pressure from consumers to access healthy food produced in an ethical way is shaping the investment allocation market. Consumers today are increasingly seeking to understand where their food comes from and how it was produced and want their food to also reflect their values – and today

that means "good for people and planet". However, consumer awareness or 'regenerative" remains low. There is a tangible opportunity to align the flows of funds with the changes in demand and lead the way it is done.

Adoption of regenerative inputs is at the core of the transformation. Unlocking the procurement power of large corporations and government in the agri-food space will help accelerate the scale of the transformation.

True regenerative carbon or nature claims (unit) is a promising opportunity to accelerate the mobilisation of funds to heal the land. Real programmes, real work on the ground and verifiable metrics will allow the demand of high-quality claims, helping companies (carbon buyers) to understand how these investments fit in their commitments – including biodiversity and nature positive commitments, and recognise nature claims as valuable investments that are not meant to be used to compensate for negative impact.

Activating the 'not obvious' leverage points in the agri-food space, will allow to re-connect the parts, accelerating real execution on the ground, unlocking economic, planet and social value in line with Ireland Agri-food Vision for 2030.

The Relevant Practices and Opportunities Table (table 6) provides relevant practices observed, and some opportunities for the Government of Ireland to explore further.

Table 8.6: *Relevant Practices and Opportunities*

	Relevant Practices	Opportunities
RP01	Cross Government Strategies on key intervention points	Implement a Cross Government Strategy on Regeneration to achieve the Government 2030 Vision • A red thread Strategy that connects all the parts so that the catalytic funding required can be mobilized in key interventions with the right instruments at the right time of the transformation. • There is a window of opportunity for the design and implementation of a systems funding model to fund the transition to regenerative agriculture in Ireland • A potential to develop a government procurement model that support climate-friendly agriculture and healthy food by increasing the role or regenerative farms in shifting billions of Euros of food purchasing dollars spent by public schools, hospitals and other institutions to nourishing, sustainable, local and equitably sourced food • Encourage private sector schools, hospitals, and other institutions to transition to regenerative procurement • The Irish government policy for a sustainable, smart agri-food sector, together with its ability to coordinate across Departments, together with the shift to a Challenge-Focused Innovation System, offers a unique opportunity to mobilise finance and develop a robust winning sub-sector within Irish agri-food

	Relevant Practices	Opportunities
RP02	Systems Models to accelerate the transformation of complex and large systems	Design and implement a Regenerative Systems Programme that accelerates the adoption of regenerative outputs. More markets, more income, less risk, faster transformation • Focuses on key impact areas and intervention points, at an entire system's level truly accelerating scale of regenerative agri-food and minimising interconnected risks • Has a clear ecosystem partnership strategy • Curates the best innovations, technical assistance, science and funders and corporates • Accelerates the technical validation of best innovations / regenerative practices in corporate and government value chains • Mobilises catalytic blended funds is strategic interventions • Monitors impact of the funds • Is transparent
RP03	Blended finance programmes to fund complex systems	Design and develop a true Regenerative Systems Funding Strategy (as a key element of the Catalytic System Programme – see RP02 • Supports the accelerated adoption of regenerative outputs • Minimises the cost of project development and operation • Attracts large amounts of diverse and fit for purpose regenerative-fit capital flows. • Promotes blended finance collaborative models to accelerate the mobilisation of private funding at more appealing risks in an orchestrated way. • Independently curates key funder types and recruit mission aligned funders from the different sectors – eg philanthropy, debt, investment etc. • Leverages key asset classes and funding instruments to support the regeneration journey • Minimise the risk of participants and ensures money flows to regenerative agri-food at the right time • Is independent • Tracks funding flows transparently with highly innovative innovation data capture and monitoring systems • Reports on the leverage and the returns of the funding catalysed through the programme
RP04	Investment case in complex integrated systems and diverse funders	Develop a Regenerative System Pathway Builds a compelling investment case in the Irish "regenerative system" pathway, with identified and de-risked returns, that helps accelerate the deployment of third-party capital in this proven path • Addresses the unrealised monetisation of value to design a compelling investment proposition to private and public funders • Attract capital and distribute value to all stakeholders
RP05	Cross sector collaborations	Coordinate across funding systems (or sponsor) • Coordination of the funding ecosystem at a systems level • The Irish government can be the coordinator (or sponsor it). Coordinates with policy • Encouraging uptake of regenerative practices by Irish farmers, using forward government procurement to pull demand, and – very importantly – supporting the knowledge programmes that are needed. Coordinates Cross sector partnerships to reduce the risk of regeneration on the ground
RP06	Nature Positive systems	Empower the agri-food funding ecosystem to act in a nature-positive way. • Exploring further how to enable the agri-food funding to implement regenerative practices at scale and at pace. This could be done through policy, its own budget, public investment institutions, and its procurement spend. • Evaluating the Integration of climate and biodiversity and its potential impact in capital flows to support the regenerative agri-food sector.
RP07	Integrated Knowledge Programmes	Orchestrate the agri-food funding knowledge exchange programme • Regenerative knowledge must be locally appropriate but based on global scientific understanding • No farmer can afford to build such knowledge. • Knowledge is also central to any form of verification (and hence valorisation) of carbon credits or bio-diversity credits

	Relevant Practices	Opportunities
RP08	True retiring carbon	Implement a tradeable regenerative unit supported by NDCs • Becoming a leader in the true carbon credits (units) space, significantly increasing the retirement rate of carbon on the ground, linked to demonstrable regeneration. • Since 2018, 69% of all Forestry and Land use issued credits were Avoidance/ Reduction credits. • Provides farmers with the opportunity to maximise their assets, create additional income and guarantees to fund the regeneration transition and thrive. • This true regenerative claim will include in addition to carbon, nature / biodiversity, soil health. It could also include social indicators to evidence community health.
RP09	Nature Claims / Units	Explore the implementation of Nature claims as an asset class • Nature units could allow Irish regeneration projects under the Net Zero vision to verify the nature or biodiversity benefits of the Ireland Net Zero regeneration programme. • A separate asset class could also make it easier for companies to invest in nature-positive projects that relate more closely to their supply chains, which in turn increase the retirement ratio and value back to the lad • Nature units can be used to invest in nature-positive outcomes. Claims that can be made upon the purchase and retirement of nature credits will be defined and linked to the relevant and reputable metrics and targets
RP10	Transparent and auditable tools	Take advantage of the significant opportunity for transparency and high quality assets • Implement a high quality and innovative transparent tracking system, to support the Irish Nature Positive or Regenerative Programmes to be delivered under the Net Zero Vision 2030 • Using new tools on top of rigorous monitoring requirements leveraging global practices – eg oracle protocols • Promote participation of funder actors to fund project development and operation, of transparent data and data capture protocols, opening the door for Irish and international tech entrepreneurs • Allowing companies to understand how Irish nature positive investment fit into their nature-positive commitments, reducing the risk of fake claims / carbons and increasing retirement rations
RP11	Aligning the Narrative	Help to bring closer together the philanthropic and the for profit space • Aligning the narrative • Minimise the public–private funding culture gap • Aligning consumer demand with funding needs and prioritisation efforts • Become a thought leader in regenerative systems funding
RP12	Challenge led regeneration innovation Programme	Implement a challenge led regeneration innovation programme to strategically identify and fund transformative innovation in the space • Leading the way to regenerative agri-food • Identify, curate and select top global innovations in the regenerative space – emerging tech – like REFI, innovative solutions for data extraction and monitoring, models, collaborations etc • Accelerating time to funds in key strategic points in a coordinated way • Influence and share findings in the global market

9. Conclusions

Author:
Saskia Visser

Credit: Unsplash

Acknowledgements

EIT Climate-KIC would like to thank the funder, authors, contributors and reviewers for their contribution to the preparation of this report.

Authors

Saskia Visser

Reviewers

Stewart Gee (EIT Climate KIC), Yasmina Lembachar (Circle economy).

How to cite this Chapter:

EIT Climate-KIC; Conclusions Chapter 9 in: Dealing with climate change and sustainability targets: The innovaton potential for the Irish agri-food sector.

Conclusions

Dealing with climate change and sustainability targets

Amidst the challenges of the climate and biodiversity crises, lies a great opportunity to transform the Irish agri-food sector and take advantage of the multiple co-benefits that a sustainable, climate smart agri-food chain can provide. This report 'Dealing with climate change and sustainability challenges' provides an array of examples that can be considered. These examples provide pieces of the overall puzzle for the transformation of the entire agrifood system. These examples should not be considered as individual options, but as a full package of well-chosen interventions will pave the road towards a net-zero food system by 2050.

Assuring a just transition

Agriculture is a critical part of the Irish economy and farming a part of many Irish peoples' livelihood and cultural identity. The sector is a boon to Ireland's economy. However, agriculture is one of the most unequal sectors in Ireland, with many farmers facing 'severe poverty'. A Just Transition approach (chapter 6) provides the foundation and is essential to assure that transformative change occurs in an inclusive and equitable manner, justice will have to become an inherent part of the future economy. There will be no need to emphasize the just transition because it will be understood that the objective of this transition is to achieve greater justice within society, in part through shifting away from ecologically damaging activities such as anthropogenic greenhouse gas emissions.

For Ireland to assure justice within carbon-neutral transition processes; inclusion is to become a principle at all levels of policy. Primary producers are included at the start and feel agency in the process. Local task forces should be established across all regions to gather nuanced perspectives and build region-specific plans for the transition's implementation. Citizen assemblies can provide fora for social dialogue across sections of society. Consumers and producers exchange and understand each other's position. These assemblies are consulted by policy makers and that can take decisions within the communities where they are active. They will become trusted as advisory bodies and citizens feel their voice is represented and there is space for dialogue and debate. Support should be given especially to women farmers who are underrepresented. Justice within transition processes addresses the procedural and recognitional.

Food system approach

A sustainable & climate smart food system does not appear overnight, especially not in our current mostly linear system. Many obstacles block the transformation. And these barriers will require interventions across all levels of governance, changes of practices by business and farmers and changes of perspectives, maybe even changes of norms and values of consumers. This system transformation will spur certain trade-offs, either locally or at the global level. Given the current prevailing market-driven system in Ireland, many interlinkages between supply and demand are present. As a result, a sustainable choice for food production in Ireland may result in negative trade-offs in another country and may have a detrimental effect on global food production. Knowing all this, makes it clear that a systems perspective, and hence a food systems approach should be the starting point of the required transformation of the Irish agri-food system. The food system considers the socio-economic and the environmental drivers that together influence the food systems activities, which all combined support the realisation of the food systems outcomes.

This is why the Irish Department of Agriculture, Food, and the Marine has partnered with EIT Climate-KIC – Europe's largest climate innovation partnership - to work with public and private stakeholders in the Irish Land Agri-Food sector to help the sector deliver on accelerated pathways for climate action and to transform the Irish Land, Agri-Food system. In this context it is important to realise that Ireland is a food exporting nation: around 90% of all food produced is exported to countries around the world. The outward-looking sector has been built on a reputation of selling high-quality, sustainable produce. Reconciling Ireland's sustainability ambitions with its plans to grow the value of the agri-food sector while also producing food within the island's planetary boundaries will require a shift in focus from volume of production to value of production. This will be a significant transition and will inevitably result in trade-offs that need to be reconciled with stakeholders across the system.

Chapter 4 explored the innovation opportunities for Ireland within the context of the circular economy and concluded that the government of Ireland has several areas that can greatly be improved. Currently, being a high-income country, Ireland typically has excessive material consumption and waste generation. Through policy legislation, with a focus on shifting attitudes and perceptions, various actors along the value chain can be supported and collaboration between stakeholders can be encouraged. Think for example on stimulation of industrial symbiosis and 'a bundle of buyers (Chapter 4 and 7'). Chapter 7 explains that there is a need for a shift in thinking away from traditional linear production models to more radical and regenerative self-sufficient business models, which is likely to require innovation and open collaboration between all stakeholders. Hence, there is a significant need for companies to come together and transparently share insights and best practices to foster more effective circular solutions in the agrifood sector in Ireland. Priority areas that have been identified in this report are i) reducing packaging and investing in development of reusable, recyclable and biobased packaging ii) tackle circularity in food processing, retailing and consumer diets and iii) adopt nature-based solutions as a preferred range of measures over technology to realise carbon neutral primary production systems.

Towards circular packaging

Chapters 4 and 7 show that due to the changing regulatory framework surrounding plastic packaging, and in particular single use plastics, Irish companies face the challenge of transitioning to more sustainable alternatives. This represents a major business opportunity for Irish companies, on the production side and on the use side. Apart from offering greater sustainability, biobased packaging and other innovative packaging solutions often provide addition functional benefits which make them more attractive. For companies that want to transition toward sustainable packaging it is recommended to start by examining how to avoid and reduce packaging for optimal sustainability performance, then explore innovations to simplify packaging for improved end-of-life management. Policy can play a role in providing support in transitioning to sustainable packaging materials assuring connections with solution providers can be made, providing clear labelling guidelines and supporting the development of additional waste management infrastructure. Finally, support will be required for innovative Irish companies (and universities) aiming to produce sustainable packaging materials, as this activity can contribute to Ireland's 2050 Climate Neutrality Targets, assist in the transition to a circular economy, along with reducing our material import dependence.

Avoiding food waste

Food waste is a major issue from a societal, environmental and moral perspective in Ireland, urgent cross-sectoral policy and industry action is needed to tackle this issue. Food waste occurs at various stages and the root causes vary between poor operations management in production to a lack of food related knowledge. Yet circular economy principles offer a potential solution to tackle food waste, by repurposing residues to new and changing thinking away from traditional linear based production systems to a more regenerative and self-sufficient system (Chapter 7). Food waste is a muti-faceted issue, hence interdisciplinary and cross-sectoral collaboration is evidently required to develop more innovative and impactful solutions to effectively tackle the root causes of food waste in the long term. Knowledge sharing and awareness building could be improved to educate industry and citizens on the negative environmental and societal consequences of food waste. Producers and retailers play a fundamental role in tackling food waste issues, stricter regulatory measures could incentivize more effective solutions being developed to minimise food waste across the value chain.

Role of dairy and meet processors in supporting the transformation.

Currently Ireland is a key player in the European meat and dairy processing sectors, yet these sectors face large challenges when it comes to realising sustainability goals. Current plans rely mostly on technological innovations and can be more ambitious. As the EU moves towards a more unified approach to food systems sustainability, compliance with new regulations will be crucial to remain at the forefront. The Irish government can play a key role in maintaining its position as a meat and dairy exporter if it stays on top of new regulations and starts implementing these sooner rather than later, in order to give its producers and processors an advantage once the regulations are passed.

Processors have an important role to play in realising the sustainability targets; they can generate the demand by providing incentives for sustainable practices; many large processors world-wide are already, successfully exploring this potential for resourcing their products. It is too early in the progress of these programs to accurately evaluate their success. It is important that the focus of sustainability target is not only on climate/carbon, but a holistic sustainability approach is preferred; no focus on per kg efficiency gains, as they often result in net emission gains due to market share increases.

Primary producers require targeted support in their interactions with food processors, as they can be highly vulnerable to fluctuations in the market. Yet, providing disincentives, for unsustainable activities will be the next step after the large-scale enrolment in sustainability programs. This will contribute to make the sustainable choice the 'new normal'.

More support is needed for processors to investigate the potential of circular economy opportunities in their own organisation and value chain. National and regional authorities play a key role in empowering processors through effective policies to facilitate sustainable circular actions in the long term.

Significant reduction of GHG emissions can be gained by applying circularity principles for energy (including heat) and water, implementing recent innovations in machinery, adoption a packaging strategy aiming a minimizing plastic use, whilst maintaining food quality standards. By broadening the business model, for instance including the alternative, plant based, proteins into the portfolio of products, processors not only reduce their own food print but also contribute to 'normalizing' onsuming a plant-based meal.

Nature based solution to meet mitigation targets

The Irish agrifood system is complex and requires multiple systemic changes to meet their climate goals. Instead of using technology, tweaking current production systems to achieve mild carbon efficiency gains per product, while production volumes continue to rise and outweigh the emission gains, nature-based solutions provide a pathway towards new, regenerative production systems. Adopting natural fertilisers (for example, green manure and compost) and locally produced livestock feed (for example, through silvopasture, rotational grazing of use of side flows of food production) have a regenerative impact on soil health and biodiversity and cut the emissions involved in the production and transport of the imported inputs. NsBs already exist and require relatively low investment in innovation - just smart implementation of nature's best 'technologies' into well-designed new agrifood systems. Chapter 1 highlights a set of NbS which will have major climate mitigation potential, alongside multiple co-benefits for climate adaptation, water quality, air quality: **i)** extensive ruminant farming (with reduced herd size), **ii)** methane-reducing feed additives for ruminants, **iii)** plant-based production systems, **iv)** nitrogen from crop system diversification and N-fixing plants, **v)** agroforestry, and vi) paludiculture (rewetting peatlands).

Carbon farming

The highlighted NbS all can be considered as carbon farming practices (chapter 2). Carbon farming can be defined as a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall.

Ireland's Climate Action Plan 2023 recognises that carbon farming can play a central role in encouraging the changes necessary to reduce greenhouse gas (GHG) emissions and to support additional environmental benefits. An enabling carbon framework is due to be developed by Q4 2023. Here it may be interesting to closely follow what is going on in Europe, to assure the national framework is in line with the European framework, which may greatly in enhance long-term success of the developments of the national carbon market. Furthermore, we strongly advice to develop a flexible framework, that allows adoption of new insights, methods and financing mechanisms as a lot of research is currently going on, which may enrich the Irish framework in development.

Chapter 8 analysed the current carbon market and warns that due to lack of standards a 'smoke credit market' has developed and current carbon payment schemes are slipping away from the original true intention to preserve our planet. Without a supported MRV, trends are that percentages of carbon retiring on the ground remain low; income flow for farmers is not increasing; and carbon farming practices can no longer be sustained or funded due to low margins.

Yet opportunities to maximise the assets of the land linked to true regeneration are emerging creating a tangible opportunity to disrupt the smoke credits market. Chapter 2 provides an overview on current knowledge on carbon farming and provide some recommendations for the development of a national carbon framework. The recommendations include providing a good baseline, training of farmer advisors on carbon farming practices, set up an (inter) national standard for MRVs, minimise administration, make sure matchmaking between supplier of and demand for carbon credits is organised, facilitate locally adapted governance to support scaling. Finally, we would like to recommend to explore the potential to extend carbon credits to nature credits, not only funding for carbon, but also the inclusion of biodiversity. This supports farmers through payment for actions implemented avoid trade-offs for other eco-system services.

Alternative proteins

In a sustainable agrifood system there is ample opportunity for the development of a market for alternative proteins (chapter 3). Ireland has potential to offer an interesting contribution to alternative proteins and other feed additives. Potential markets that can be developed are those of plant based and ocean based alternatives for human nutrition, the feed additives; especially where it delivers methane reduction, circular feed production in which fungi, insects, algae, fish cut offs and seaweed have an important role to play, yet the role of grass as a protein source can also be further explored. To

fully benefit form the potential of an emerging market for alternative proteins for both food and feed, it is important to develop a policy supported protein strategy, which also includes the ambition for the animal-based proteins in the diets. The strategic plan to support native protein production form the Irish protein stakeholders group provides a good start. Yet, a cross government strategy on alternative proteins is needed to stimulate the production of either plant based, ocean based and/or circular proteins for food and feed and to align to agendas for both the tillage sector, marine sector, and the livestock sector. The protein strategy will support a compelling investment case in a sustainable system pathway, with identified and de-risked returns, that helps accelerate the deployment of third-party capital (chapter 8).

Funding the transition

A systems' approach is not a 'nice to have' but a fundamental requirement when funding a transformation of the size of the Irish agri-food system. Funding at the pace and scale that is required will continue to fail without a holistic view of the system, with a clear understanding of key leverage points, interconnected risks, and value generation. A diverse group of funders are becoming more and more aware of the monetization value of regeneration & sustainability. Confidence levels in the ability to actually transition towards a true sustainable and carbon neutral system is still low, delaying the flow of existing, and vast, flows of capital to the regeneration agri-food sector. Collaborative capital is the way forward, as they enable the provision of funds in key intervention points at the right time, and help minimise the risk for the participants, when adequately structured. Flows of funds are available but allocations in sustainable agri-food remain still low, vis `a vis total funds allocated to agriculture and other key sectors of the economy. New mission-aligned entrants as well as blended structure participants have a golden opportunity to accelerate the allocation of strategic funds for the mobilisation of additional private finance towards sustainable agri-food.

Adoption of sustainable and/or nature-based inputs is at the core of the transformation. Unlocking the procurement power of large corporations and government in the agri-food space will help accelerate the scale of the transformation. True regenerative carbon or nature credits are a promising opportunity to accelerate the mobilisation of funds to heal the land. Real programmes, real work on the ground and verifiable metrics will allow the demand of high-quality claims, helping companies (carbon buyers) to understand how these investments fit in their commitments – including biodiversity and nature positive commitments, and recognise nature claims as valuable investments that are not meant to be used to compensate for negative impact. Activating the 'not obvious' leverage points in the agri-food space, will allow to re-connect the parts, accelerating execution on the ground, unlocking economic, planet and social value in line with Ireland Agri-food Vision for 2030.

Deep Demonstration to facilitate collaboration and sensemaking, realising a carbon neutral agri-food system

Deep Demonstration includes methodology and processes to help deliver systemic innovation, which includes working with governments, regions, cities and/or industries to provide support for large scale transformational change through an integrated, systemic approach to innovation, education and capacity building, entrepreneurship and policy design. The scope of a deep demonstration is to provide inspirational examples of what is possible, showcasing a resilient future and highlighting the ways that innovation across whole systems can unlock the change we need to achieve a net zero agri food system. This report feeds the development of co-designed portfolios of connected innovation actions (including policies) and projects to generate options and pathways for accelerated transformation of the entire Irish Agri food system. By combining the portfolio of actions to sensemaking, a form of fast learning including a rapid evaluation and sharing of what works and what does not, at the centre of the process, connected and supportive decision making, and planning is facilitated, which ensures speeding up the transformation.

Climate-KIC

Co-funded by the European Union

climate-kic.org