# REPORT 2: Enabling farmers to transition to circular farming practices

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# TASK REQUIREMENTS

*Report 2 'Enabling farmers to transition to role model farming'* is the second of three reports that responds to *Task 5 'The Role Model Farmer'* of the *Co-BioEcon* project (2021-2027). These reports stand-alone but it is recommended they are read consecutively for context.

Sub-task 5.2 'Enabling farmers to transition to role model farming' contains two further sub-tasks:

4. To investigate barriers and find solutions for transitioning to more sustainable farm practices.

5. To enable farmers to transition to more sustainable pathways in ways that protect their livelihoods.

# 1. INTRODUCTION

## 1.1 The bioeconomy

The bioeconomy has many interpretations across time and sector. It is the part of the economy which uses renewable resources such as crops, forestry, and fisheries to produce food, products and energy, while also reducing waste. Developing the bioeconomy means diminishing reliance on fossil-based fuels and carbon intensive resources and boosting the use of renewable biological resources. Viaggi (2025) identifies current definitions of the bioeconomy as falling within five overlapping dimensions, namely: processes, products and sectors involved in the bioeconomy as a meta-sector; technologies and innovations; drivers, motivations, properties, economic problems and reasons for making a case for the bioeconomy; academic disciplines addressing the bioeconomy, and 'visions' of the bioeconomy. Most definitions involve a mix of these five dimensions. In this report, the definition contained in the *Strategic Framework for a Competitive and Sustainable EU Bioeconomy* (European Commission, 2025, p1) is utilised which defines the bioeconomy as:

> 'activities that deliver sustainable solutions based on biological resource to create added value. These include products, services, science and technologies benefiting sectors ranging from agriculture, forestry, fisheries and aquaculture to value chains based on biomass processing, biomanufacturing and biotechnologies such as food, health, energy, industry, ecosystem and other services.'

This definition is useful because it accommodates the multiple conceptualisations of the bioeconomy currently identified in the literature. However, scaling bioeconomy industries significantly impacts land use, raising vital questions about food security, carbon sinks, biodiversity, and ecosystem preservation. For example, expanding the cultivation of energy crops or industrial wood can compete directly with agricultural land used for food production.

## 1.2 Conceptualisations of the bioeconomy

The bioeconomy is an evolving concept having first emerged in European economies with respect to biology and biotechnology with rapid increase in use and conceptualisation since 2005. Bugge et al. (2016) conceptualise the bioeconomy in the form of 'ideal types': a bio-technology vision that emphasises bio-technology research, application and commercialisation of bio-technology in different sectors; a bio-resource vision that focusses on the role of research, development, and demonstration related to biological raw materials in sectors such as agriculture, marine, forestry, and bioenergy as well as the establishment of new value chains; a bio-ecology vision that highlights the importance of ecological processes that optimise the use of energy and nutrients, promote biodiversity and avoid monocultures and soil degradation. The biotechnology visions' point of departure is in the potential applicability of science, the bio-resource vision emphasises the potentials in upgrading and conversion of biological raw materials, with the latter emphasising the potential for regionally concentrated circular integrated processes and systems.

Vivien et al. (2019) adopt a 'narrative' approach that identifies three types of bioeconomy. Type I: considers the limits of the biosphere, Type II: a science-based bioeconomy and Type III: a biomass-based bioeconomy. Mougenot and Doussoulin (2022) also identify three trajectories in the development of the concept of the bioeconomy. The first developed from an ecological perspective, the second from a green growth perspective while the third is based on innovations which replace dependence on oil resources, through the exploitation of biomass. Given these conceptualisations, the bioeconomy has the potential to address major societal challenges but is not inherently sustainable (without intentional design), as it is constrained by planetary boundaries, impacts of climate change and the sustainability of biomass. In addition, land use 'competition' means that biomass needs to be generated from excess farm residues not generated from land needed for food production (Fritsche et al. 2010). Furthermore, the 'rebound effect' of resource efficiency is often overlooked in assessments of the potential and efficacy of the bioeconomy to solve societal challenges (Ramanaukse et al. 2023). Thus, these conceptualisations (and their limitations) have meant that the bioeconomy has been re-defined and re-conceptualised in multiple ways in different contexts over time, with

no agreed or consistent cross-sector shared understanding of the term currently in place. In addition, there are related terms associated with the bioeconomy which are often used interchangeably, albeit, they all have distinct and overlapping interpretations.

The circular economy and circular bioeconomy are often used interchangeably with the bioeconomy, even though they have individual rationalisations. For example, while the bioeconomy uses natural resources as raw materials, the circular economy aims to keep raw materials looping for as long as possible, while generating the lowest possible amount of waste and pollution (a process known as circularity). Circularity refers to practices that optimise resource use and minimise waste across the entire production and consumption cycle, emphasising sustainability and economic efficiency. Circularity is measured by the circularity material use rate, that is, the percentage of material resources used in an economy that come from recycled, recovered, and fed-back materials, rather than from new, virgin extractions. Circularity is now considered an essential component of the bioeconomy, even though it developed to some extent independently from the concept of the bioeconomy (Fasolino et al. 2025). Currently our systems operate in a ‘take-make-waste’ system (also known as a linear system/process/economy), where we take raw materials from earth, make products from them and eventually dispose as waste. Much of this waste ends up in landfills or incinerators. The circular bioeconomy, on the other hand, uses readily renewable natural resources as raw materials (including organic waste) while emphasising the importance of biodiversity and nature preservation, with end-of-life products designed as far as possible to be biodegradable, thereby improving soils. The EU highlights the synergies between the two approaches and states that to be successful, the European bioeconomy needs to have sustainability and circularity at its heart - evident in the increased use of the circular bioeconomy term from 2018 and the EU's updated bioeconomy strategy. Consequently, European policy and research focus is shifting towards the concept of the circular bioeconomy or circular economy which is defined as:

> ‘A system which maintains the value of products, materials and resources in the economy for as long as possible, and minimises the generation of waste. This means a system where products are reused, repaired, remanufactured or recycled’
>
> (EU, 2026)

The discussion so far clearly paints a picture of the bioeconomy that has multiple understandings and interpretations. To understand these further, it is important to contextualise the broader research environment in which discussions are taking place.

### 1.3 Bioeconomy research

In tackling climate change, enhancing food security, protecting nature and biodiversity, the bioeconomy is a central component. Consequently, research is crucial in that it helps connect technology, innovation, economics, natural resources and sustainability. Wei et al. (2022) identifies four stages of bioeconomy research. An infancy stage (1998-2002) characterised by fisheries management and economic modelling research; an exploring stage (2003-2012) where the main topics were marine reserves, population dynamics and biofuel; a blooming stage (2013-2017) focussing on sustainable and renewable bio-based products, biotechnology, new agricultural systems and bioeconomic policy research and finally, a maturity stage (to date), where dominant topics are the circular economy and future economic and industrial transformation. Fasolino et al. (2025) examine the bioeconomy and circular bioeconomy, to explore implications, trends and gaps from an economic perspective. Seven topics are identified including; the bioeconomy framework, technology and innovation, organisational, management and economic perspective, consumers, agriculture, policies and sustainability. Interestingly, the authors indicate that bioeconomy and circularity are distinct concepts, with the bioeconomy not implying circularity, meaning the circular bioeconomy needs to be achieved through a deliberate policy strategy backed by supporting research. Understanding these definitions, conceptualisations, theoretical frameworks and, linking these to practice, are central to the success of the bioeconomy for all stakeholders, particularly government and policy makers, who set the agenda for others such as businesses and primary

producers to operate in. A key concern of bioeconomy development to date is that 'trade-offs' between bioeconomy objectives need to be minimised (Ruml et al. 2025), particularly in relation to the environment and climate change whilst maximising synergies.

The bioeconomy also nestles within overlapping theoretical frameworks within sustainable transition theories. The field of sustainable transitions research has emerged in the last two decades to explore how societies and systems can shift towards more sustainable practices in response to environmental and social challenges. Sustainability transitions research examines processes of long-term, structural shifts in socio-technical systems towards more sustainable modes of production and consumption. This field can be broken down into three main components: 1) socio-technical systems, 2) transition processes 3) the contested character of sustainability (Markard, 2012). The bioeconomy, within sustainable transition theories, can be grounded in a technocentric or ecocentric view. The technocentric view dominated the narrative endorsing economic growth and therefore development. For example, technological progress is identified as one way in which resource constraints can be overcome and continuous economic growth maintained. New technologies continue to be perceived as capable of offsetting problems related to environmental degradation. However, current economic growth is proving to be unsustainable, evidenced by the likely failure to reach Sustainable Development Goals (SDGs) by 2030 (Stavytskyy et al. 2025). Developments are happening across multiple components be that technology, institutional, political, social or economic. The challenge will be to continually draw from previous and current iterations to improve future decision-making trajectories. Knowledge of technocentric and ecocentric paradigms along with sustainability transitions research is important to both government and policy makers, who are charged with translating theory into policy across the social acceptance triangle (socio-political, community and market).

### 1.4 Farmer's position in the bioeconomy

Bühler et al. (2026) identify the many roles that farmers fulfil in the bioeconomy as producers and suppliers of food and biomass; as biomass processors, implementers of sustainable agricultural practices; as drivers of a sustainable and circular

bioeconomy (food) system; as custodians of local knowledge and innovations; as managers of landscapes; as contributors to rural development, and as enablers of the nexus between nature and industry. Whilst these roles may be obvious, Goulet (2013) identifies that 'local food producers are often misunderstood and undervalued for their contributions to food systems and as stewards of the land, with their knowledges and experiences ignored or inaccurately reflected in food and agricultural research, decision-making, policy, regulation and planning. Linking to this, O'Connor et al. (2025, p566) focus on short food supply chains operated by local farmers, recognising local farmers as essential for societal transitions to sustainable food systems 'particularly their experiences, knowledges and contributions'. Fasolino et al. (2025, p229) note that 'agriculture has a special place in the circular bioeconomy providing an "anchoring" between territories, ecosystems, and value chains, based not only on the physical infrastructure but also on socioeconomic structures', which as a sector has been overlooked. This is re-enforced in Ireland, where farmers, as primary producers, are identified as key contributors who also appear to be marginalised in the emerging bioeconomy (Harrihill et al. 2023). This is concerning given that agriculture is identified as central to the development of the bioeconomy and a major component of the Irish economy, with the agri-food sector accounting for 9% of goods exported (almost €19bn) and 6.4% of total employment, with land use comprising over 4.6 million hectares of agricultural land and over 808,000 hectares of forestry (Government of Ireland, 2025). Government bodies and academic institutions appear to dominate the decisions and direction of the Irish bioeconomy and farmers seem to be pushed to the margins (Harrihill et al. 2023), presenting a contradictory picture of the determination to grow the bioeconomy and be part of the EU vision to 'deliver sustainable solutions based on biological resource to create added value' (EU, 2025 p1).

# 2. LITERATURE REVIEW

Transition is a complex process that requires transformation and in simple terms, transition barriers to the bioeconomy are obstacles that slow the shift from a fossil-based system to a renewable, bio-based one. The first step in this transition process is the identification of barriers that are hampering the transition to the bioeconomy.

## 2.1 Barriers

- **Definition of the bioeconomy**

There is no agreed definition of the bioeconomy and this present a significant barrier to the bioeconomy transition. McCormick and Kautto (2013) provide an overview of the bioeconomy in Europe. Their results show that definitions of the bioeconomy are evolving and vary depending on the actor but display similarities such as the emphasis on economic output and a broad, cross-sectoral focus. To advance a sustainable bioeconomy, the authors draw attention to further actions, i.e. participatory governance that engages the public and key stakeholders in an open and informed dialogue, as well as a commitment by government and industry to innovation that drives concerted efforts on sustainable development of the bioeconomy. Bugge et al. (2016) identify little consensus concerning what the bioeconomy actually implies in their bibliometric analysis of the origins, uptake, and contents of the term 'bioeconomy'. Their results show that the bioeconomy research community is still rather fragmented and distributed across many different fields of science, with natural and engineering sciences take up the most central role. In recent years, Vivien et al. (2019) state the term has been 'hijacked' and a 'buzzword' used by public institutions to announce and describe a supposed current economic and ecological transition. To support this claim, they analyse three different interpretations of the term bioeconomy, presenting each of them as narratives combining distinct visions of future economic development, technical trajectories and imaginaries associated with a particular relationship to nature. Some problems linked to defining the bioeconomy connects to its conflation with the circular economy/bioeconomy as a nested and or individual concept (the bioeconomy replaces fossil fuels with renewable biological resources, while the circular economy eliminates waste and keeps all materials in use, regardless of their origin). Writing more recently, Thomchick et al. (2024) note that given the

enormous scope of the bioeconomy, a clear and consistent definition of bioeconomy is still lacking. Without an agreed definition, it follows that policy creation, development and implementation may be impacted.

- **Fragmented policy development**

Another barrier links to bioeconomy policy development (including instruments). Gould et al. (2023) locate the concept of a 'sustainable bioeconomy' using bibliometric analysis to identify that the bioeconomy as a policy and research concept is relatively new but growing, with European countries (specifically in North and North-West Europe) taking charge. Topics of bioenergy and forestry are most prevalent, reflecting policy areas that can be said to pre-exist bioeconomy strategies. Proestou et al. (2024) provide a global analysis of bioeconomy visions in governmental bioeconomy strategies. The study examines the bioeconomy visions presented in 78 policy documents from 50 countries worldwide, using qualitative content analysis. 227 distinct policy goals were identified and analysed. The results reveal that goals and visions prioritize economic growth, while environmental considerations are less salient. The bioresource vision emerges as the globally dominant perspective, while the bioecology and biotechnology visions have lower salience. Dietz et al. (2024) locate trends and drivers of national programs and policy to identify recent mega policy trends along with trends in agenda and contexts. They identify that developing and emerging economy countries are increasingly engaged and, through their bioeconomy strategies, seek to adapt existing technologies (e.g., biorefineries) to local conditions. These efforts aim to address persistent social and economic challenges and usher in immediate change (e.g., job creation). Turning towards agendas and their contents, the authors identify the trend towards addressing potential regional biomass supply deficits and the move towards specific capacity-building programs are proposed to equip individuals with the necessary knowledge and skills for an effective contribution to the bioeconomy. Goritz et al. (2025, p344) draw on policy data from over 50 countries and identify:

> *'bioeconomy policies are dominated by economic and nodal instruments focused on promoting innovation, research and development, while regulatory*

*instruments, particularly those addressing environmental issues, are rare within the strategies themselves. Moreover, while bioeconomy strategies contain a significant number of statements about instruments, they rarely specify their calibration. These patterns suggest that while bioeconomy strategies play important agenda-setting and signalling roles, their limited balance and calibration may constrain their ability to provide actionable policy guidance'.*

In addition, the authors note the eventual impact of public policies on the bioeconomy will depend on the selected policy instruments, i.e. the techniques or means used to attain policy goals.

- **Lack of policy coherence**

Tackling the three planetary crises requires enhancing capacities and mechanisms to enhance policy coherence at all levels. Policy coherence involves systematically promoting mutually reinforcing policy actions across governments and agencies, fostering an integrated approach to the achievement of sustainable development goals its three dimensions: economic, environmental and social. Enhanced policy coherence establishes the conditions necessary for achieving policy integration for effective environmental governance for delivering on the environmental dimension of sustainable development (UN Environment Programme, 2026). Focussing on EU policy coherence, Muscat et al. (2021) assess policy coherence between EU bioeconomy and agro-food goals, focusing on interactions, trade-offs, synergies, and uncertainties. The authors analysed 41 EU policy documents across waste, bio-based industry, environment, renewable energy, and agro-food domains. Overall, bioeconomy and agro-food policies are perceived as largely coherent, with waste policy offering the most synergy. Key agro-food goals like food security and waste reduction benefit from bioeconomy policies, but uncertainties remain. Disagreements and vagueness highlight the need for clearer definitions, better framing, and adaptive governance. Embracing complexity and context-specific approaches is necessary for effective policy integration and sustainable biomass management.

- **Economic cost**

A further barrier connects to the economic cost of transitioning to the bioeconomy. Kircher (2019) identifies that to achieve the objectives of the *Paris Climate Change Agreement*, the conversion of our economy, which is still dominated by fossil carbon, to the bioeconomy model must be completed by 2050. He further acknowledges 'the future bioeconomy will have to concentrate on the food, chemical and heavy fuel sectors. Important sub-areas are alternative animal protein for nutrition, feedstock efficiency in the processing of bio-based raw materials, and the expansion of the raw materials spectrum. This requires enormous investment in industrial facilities, the integration of newly emerging value chains and the necessary infrastructure'. Khanna et al. (2024) note that a key complexity in charting a path to a circular bioeconomy is selecting the mix of technologies and the desired extent of circularity to be achieved with this transition, the authors adopt an economic value-based lens to balance the desire for circularity with its costs, benefits, and distributional effects on society. This perspective analyses the mechanisms that sustain the existing linear economy and proposes a novel social cost-benefit framework to determine the optimal level and path to circularity. They present five critical pathways to achieve a sustainable circular bioeconomy in a market economy consisting of decentralized decisionmakers. Ma et al. (2025) adopt a different approach and examine two supply chains, biochar and black soldier fly, whilst also acknowledging that supply chains remain in their infancy. They propose a conceptual model that characterises the farm decision to adopt the use of circular residues.

- **Infrastructure deficits**

Connected to the need for increased capital, is the fact that currently there is limited bioeconomy infrastructure in place that supports the comprehensive development of the bioeconomy. Infrastructure in this sense relates to multiple aspects, hard and soft infrastructure. An example of this is provided by Chelala and Amazonas (2024) who focus on Amapá in Amazonia and the cultivation of what they term 'bioeconomy sectors' like açaí, Brazil nut, cocoa, and fish. Drawing on data from family farmers amongst other stakeholders they note the importance of these products for socio-economic development and cultural identity. The results show that poor roads,

unstable energy supply, and limited connectivity hinder value addition, reinforce dependence on middlemen, restrict innovation, and deepen inequalities. The study highlights the need for inclusive public policies, investment in physical and digital infrastructure, and renewable energy expansion to boost the regional economy and reduce social vulnerabilities.

- **Sustainability, cascading use and regeneration of biomass**

Biomass is derived from organic material and the majority of biomass produced by EU agriculture comes in the form of biogas, and feedstocks for making biodiesel and bioethanol. Agricultural biomass is organic material from farming, consisting primarily of crop residues, dedicated energy crops, and animal waste. The sustainability of biomass plays a central role in the development of Europe's bioeconomy (Morone et al., 2026). Cascading use refers to efficient resource strategy that prioritizes material uses—such as manufacturing, reusing, and recycling—before utilizing the organic material for bioenergy or final disposal. This is known as the biomass valorisation hierarchy (Cansado et al. 2025) which means the maximum economic and environmental value from a single harvest. Regeneration of biomass means the natural or managed process where organic matter grows back, or when used biomass-derived materials (like biochar or activated carbon) are cleaned and restored for reuse. Key concepts include natural regrowth, material restoration, and supply chain renewal. Almeida et al. (2025) conduct a systematic review to recent advances (2021–2025) in the conversion of agricultural biomass into biomaterials, biofertilizers, and bioproducts. Studies involving a wide range of agricultural biomasses (e.g., rice straw, corn stover, wheat straw, and sugarcane bagasse) were evaluated. Main outcomes included the development of bioplastics, biofoams, composites, hydrogels, bioceramics, biochar-based fertilizers, organic acids, enzymes, and green solvents. Evidence consistently indicated that pretreatment strongly influences conversion efficiency and that enzymatic and thermochemical routes show the highest potential for integrated biorefineries. Limitations included heterogeneity in biomass composition, variability in methodological quality, and scarcity of large-scale studies. Overall, findings underscore agricultural biomass as a strategic feedstock for circular bioeconomy models, with implications for sustainable materials, renewable energy,

and low-carbon agriculture. Continued innovation, supportive policies, and improved logistics are essential for scaling biomass-based technologies. In Ireland, Giron-Domingues et al. (2025) provide a holistic county-level biomass map for the Republic of Ireland, covering primary feedstocks (PFs) and secondary feedstocks (SFs, i.e., by-products and waste, in total 221 feedstocks were mapped. The mapping indicates that environmentally sustainable bio-based value chains (BBVCs) requiring large amounts of solid or liquid SF should prioritise processing sites near major feedstock sources in the southeast and southwest of Ireland. The northwest and east coast have the lowest availability, while the west and midlands have the most variety in quantity and type of feedstock. Counties with abundant feedstocks do not necessarily have high feedstock diversity, except for Cork. Talwar et al. (2025) focus specifically on Counties Tipperary and Monaghan to quantify and characterises biomass wastes at farms, food production, and forestry settings where they note wide differences. The authors conclude that it is especially important to engage local stakeholders to build co-operative models for biomass valorisation. They conclude that not only is this environmentally beneficial, but also socially and economically advantageous. Creating indigenous fertiliser and energy sources is important for the island of Ireland, not only in meeting market demand, but also in reducing greenhouse gas (GHG) emissions and achieving emission reduction targets.

- **Competition for land**

The need to develop the bioeconomy also leads to increased competition for land and resources. Hertel et al (2013) identify this emerging issue in the global economy relating land use competition to biofuel expansion and indirect land use change. The authors offer a simpler modelling approach and uncover additional insights regarding the global land use impacts of biofuels over the years. Grossauer and Stoeglehner (2023) focus on the ‘spatial framework conditions’ necessary for what they term the ‘future-orientated bioeconomy’ in a systematic review of scientific literature relating to the bioeconomy to reveal that spatial aspects are rarely discussed, and large research gaps are evident. These gaps relate, for example, to the development of planning instruments for the protection of agricultural land, or the assessment of the influence of intensification of agriculture on biodiversity or the multifunctionality of landscapes.

In addition, the social aspects of transitioning to a bioeconomy, the role of regional planning with respect to decentralised versus centralised models, and the influence of policy and governance to foster a sustainable transition process and to avoid land use conflicts are all topics which need to be addressed in research. In relation to Ireland, Geoghegan and O'Donoghue (2024) use spatial microsimulation analysis to examine the spatial aspect of the production of renewable energy feedstocks (grass silage and short-rotation coppice willow). The results show that midlands counties, especially those in the north midlands, have the highest proportion of land where feedstocks would be more profitable than the current agricultural use. Counties on the western seaboard have the lowest proportion of land where feedstocks would give greater returns. Of the two feedstocks assessed, short-rotation coppice willow cultivation is more profitable than grass silage production. The overwhelming majority of land where producing feedstocks would be more profitable has cattle farming as its current use.

- **'Sustainability' of the bioeconomy and alignment with SDGs**

Pfau et al. (2013) note the association of the bioeconomy with sustainability as an 'assumed relationship' following their review of 87 scientific journal articles. Their results show that visions about the relationship between bioeconomy and sustainability differ substantially. Four different visions were identified, including: (1) the assumption that sustainability is an inherent characteristic of the bioeconomy; (2) the expectation of benefits under certain conditions; (3) tentative criticism under consideration of potential pitfalls; and (4) the assumption of a negative impact of the bioeconomy on sustainability. The 'crucial role of sustainability is identified as a path transition towards by the bioeconomy' by Gawel et al. (2019) and requires (1) sustainability of the resource base and (2) sustainability of processes and products, especially by (3) circular processes of material fluxes, not least to gain consumer acceptance for bio-based products. They further argue that that innovative governance is necessary to reduce competitive drawbacks compared to fossil resources to secure ecological, social, and economic sustainability requirements. Warchold et al. (2025) note that the bioeconomy is as a key national development strategy for sustainable economic growth, environmental restoration, and achieving the Sustainable Development Goals (SDGs). Despite this potential, the bioeconomy is not inherently sustainable nor circular, and policymakers pursue bioeconomies to

different extents, facing challenges in balancing synergies and trade-offs with the SDGs. The authors examined bioeconomy strategies presented in 29 policy documents from 14 European countries and the European Union. Using text analysing techniques, they evaluated the extent to which bioeconomy strategies determine the salience of sustainability. Their analysis shows that most bioeconomy strategies emphasize opportunities aligned with SDGs 6 and 12–15, focusing on environmental objectives within the planet pillar of the 2030 Agenda. However, these strategies often neglect the principles of 'equitable' and 'fair & inclusive' transition and fail to consider potential unintended consequences or trade-offs for sustainability. This disconnection is further reflected by a significant divide between evidence on bioeconomy–SDG interactions and the narratives presented in policy documents. The concepts of sustainability and circularity are theoretically integrated into bioeconomy strategies but often remain lethargic, focusing on narratives rather than evidence on existing trade-offs at the expense of human needs and ecosystems. To prevent the risk of unsustainable transitions, they recommend that bioeconomy strategies should evolve toward systemic approaches that emphasize resilience, equity, and ecological regeneration. Commenting on the recently published EU Bioeconomy Strategy (EU, 2025) in conjunction a targeted review of EU strategies, official assessments, and international reports published between 2018 and 2025, complemented by selected peer-reviewed literature on the circular bioeconomy, innovation systems, and biomanufacturing, Morone et al. (2026) seek to synthesise major strategic developments, identify systemic gaps, and propose actionable priorities for implementing a competitive and sustainable EU bioeconomy.

- **An inclusive and equitable bioeconomy – the agricultural just transition**

Van der Veen et al. (2026) identify that a successful and sustainable bioeconomy relies not only on technological innovation but also on its integration into social contexts and this is especially important considering the current position of farmers in the social bioeconomy network. The authors draw on three contrasting case studies and focus on stakeholder inclusion, distributive justice and context sensitive implementation. Their results underscore the importance of a pluralistic, stepwise approach acknowledging that full inclusion may not be feasible initially in all contexts particularly where 'enabling environments are weak' and argue 'that inclusive learning and

adaptive strategies are essential to balance ideal goals' (Ibid.). Literature in relation to an agricultural just transition initially emerged in relation to climate change (see Blattner, 2020). Linking this to farmers, the need for an agricultural just transition in hand with just food transition system has been identified (Kaljonen et al., 2023). More recently, the turn has been towards the use of agroecology to create sustainability of food systems. In simple terms, agroecology is a holistic approach that blends science, agricultural practices, and social movements to design and manage sustainable food systems by working with nature. It optimizes the interactions between plants, animals, humans, and the environment while promoting fair and inclusive communities (farming with nature). Wezel et al. (2021) present an extensive literature review of concepts, definitions and principles of agroecology, and their historical evolution, considering the three manifestations of agroecology as a science, a set of practices and a social movement, based on this they develop a consolidated list of principles in the context of presenting transition pathways to more sustainable food systems. The authors determine: (1) Definition of 13 consolidated agroecological principles: recycling; input reduction; soil health; animal health; biodiversity; synergy; economic diversification; co-creation of knowledge; social values and diets; fairness; connectivity; land and natural resource governance; participation. (2) Confirmation that these principles are well aligned and complementary to the 10 elements of agroecology developed by FAO but articulate requirements of soil and animal health more explicitly and distinguish between biodiversity and economic diversification. (3) Clarification that application of these generic principles can generate diverse pathways for incremental and transformational change towards more sustainable farming and food systems. (4) Identification of four key entry points associated with the elements: diversity; circular and solidarity economy; co-creation and sharing of knowledge; and, responsible governance to enable plausible pathways of transformative change towards sustainable agriculture and food systems. Ceddia et al. (2024) focus on the complete integration of food systems within global capitalism to locate the transformative power of agroecology citing its double nature: concrete (technical) and social (political). By acting in both dimensions, the authors argue that agroecology can help reorient food systems away from profit accumulation and towards better meeting community needs, in line with the tenets of food sovereignty. Focussing on Finland, Kuhmonen and Stiljaoja (2022), identify that many farms are operating on the verge of financial

profitability, especially in geographically disadvantaged peripheral regions with a limited range of production opportunities. Using the concept of resilience, they analysed farmers' capacities for transformation. The results from their farmer survey indicated that the regime exerts a strong cost-price squeeze on farmers, escaping of which is difficult also for farmers deliberately seeking new pathways beyond it. Due to farmers' dependence on the regime, drastic changes to 'the rules of the game' could undermine their resilience. The authors argue that for transition processes to be both sustainable and just, proactive restorative justice should aim at promoting resilience at the farm level by deliberately building inclusive and accessible transition pathways. Still in Finland, Huttunen et al. (2024) note that justice in sustainability transitions requires states to design transition policies that leave no-one behind. Emphasising fairness, however, may entail slowing or scaling down the impetus of sustainability transition. The authors analysed how stakeholders frame justice in deliberating policy measures needed to support just transition in agricultural land use and dietary changes, the cornerstones of building healthier and climate friendlier food systems in Finland. The results show that justice frames focus on the potential impacts of transition, largely ignore global scale, and prioritise social justice claims at the cost of environmental ambition. To create just and environmentally effective policies, policymakers need to consider justice at the level of policy-mixes combining environmental and social policies. Furthermore, they need to acknowledge systemic injustices present in existing systems while striving towards just transition. Connecting the concept of a Just Transition to Ireland, Moore-Cherry et al., (2025) adopt a place-based and co-creation approach. Pin-pointing 'conversion factors' (personal, environmental, social and economic), the authors state paves the way for understanding barriers to and pathways towards a just transition in particular places. Furthermore, the research identifies the need to interrogate the relevance of the just transition to particular communities and to recognise 'varieties of transitions' matched to local conditions. They argue that a just transition must be seen within the wider history of regional, social and spatial inequalities. Garvey and Moore (2025) state that given some of the unique characteristics and land use in Ireland, transition in this sector is characterised by high levels of social, economic and political sensitivity. They define a transition in agriculture and land use not as a transition out of agriculture, but a transition into making optimal use of our land and agricultural resources and

'something that would and should be done with farmers and rural communities, that should be opportunities-led as well as recognising and mitigating associated costs' (Ibid. p136). The authors identify eight interventions which they formulate into an *Integrated Framework for Action,* and they locate the active participation and engagement of farmers innovating and changing practice across a diversity of contexts as fundamental to effective transition. While it is important to identify the barriers to the development of the bioeconomy, glimmers of opportunity rest in the identification of pathways which are set out below.

## 2.2 Pathways

Drivers of the implementation of a sustainable bioeconomy are factors that propel the use of renewable biological resources—such as plants, microbes, and forestry—to produce food, energy, and industrial goods. Drivers are identified as exogenous or endogenous bioeconomy drivers.

- **Scientific advances**

In general terms and writing from a scientific perspective, von Braun (2022) states that the bioeconomy is exogenously driven by recent advances in basic science facilitating bio-product innovations, and by the increasingly recognized need to address the ecological problems of the Anthropocene (aka the grand challenges). The bioeconomy is endogenously driven by established evidence of opportunities in bioeconomy that leads to investments, by strategic science policy getting proactively engaged, and by scale and network effects. For these endogenous drivers, people do matter, in particular visionary policy makers, corporate investors, scientists, and strategists.

- **Diverse bioeconomy strategies**

The Food and Agriculture Organization of the United Nations (FAO, 2024), for example, in their attempt to guide global discussions on the bioeconomy provide a set of eight recommendations. These are: achieving food security and nutrition through the transformation of agrifood systems, as a primary principle for developing the bioeconomy agenda; leveraging the potential of the bioeconomy to enable a holistic

carbon management, alleviating pressure on natural resources and address climate change; scaling up investments in science, technology and innovation for agrifood systems in the bioeconomy; developing holistic, practical and transparent bioeconomy policies, strategies and plans; promote the bioeconomy for rural-urban transformation; harnessing the potential of the bioeconomy for inclusive development and a Just Transition; establishing globally accepted criteria for sustainable bioeconomy and, finally, fostering global cooperation for sustainable bioeconomy. Devaney and Henchion (2018) cite international learnings for bioeconomy development, noting that diverse national contexts require the development of diverse bioeconomy strategies. Stakeholder inclusion and value chain analyses are essential for informed bioeconomy strategies, in addition, robust sustainability assessments, support frameworks and integrated value web approaches are key.

- **Combination of temporal, environmental, economic and social factors**

Turning towards Europe, Paterman and Aguilar (2018) outlines the context and circumstances that favoured the development of a Bioeconomy Strategy in the European Union (EU) and the role played by the different Framework programmes for Research, Technological Development and Demonstration and suggest the birth of the bioeconomy in the European Union (EU) has been the result of chance and necessity. Wozniak et al (2021) also focus on Europe and specifically on Poland to identify bioeconomy development factors such as environmental, economic and social factors. They note that raising knowledge and public awareness requires engagement of various stakeholders. More recently, Briers et al. (2026) identify elements of successful bioeconomy pathways in relation to a multi-regional European perspective: investment in innovation, scientific information, stakeholder co-operation, supportive regional policy and demand for bio-business and products. They identify supporting conditions for bioeconomy development include governance, investment and awareness.

- **Drivers of a sustainable bioeconomy**

Sala-Ríos et al. (2026) analyse the drivers of a sustainable bioeconomy paradigm to identify six interrelated drivers that form the basis of a sustainable bioeconomy: just

transition; a (re)productive bioeconomy grounded in ecological limits; the integration of the environmental, social and governance (ESG) criteria into corporate decision-making; collaborative strategies; territorial rootedness; and state support. Moving to Ireland, Devaney and Henchion (2018) use Ireland as a case-study. The authors undertook a Delphi study with 75 bioeconomy experts in Ireland to assesses and prioritise value chain opportunities for the Irish bioeconomy drawing on the *BioEire* project (Walsh et al. 2017). They point out that the bioeconomy can be successful economically, environmentally and socially if developed under certain conditions, and there is potential for nations to learn from one another as to what they term 'consensus, caveats and conditions' might encompass. They suggest this includes consideration of factors from supply to demand, including the scale and fragmentation of feedstock, the capital investment required at the transformation technology stage and consumer acceptance of the biobased output. The need for robust environmental sustainability assessments, clear support frameworks, adherence to cascading and circular principles and integrated value web approaches are also highlighted through their analysis.

# 3. RESULTS AND DISCUSSION

Multiple operational, social and familial barriers to the development of the Irish bioeconomy were identified by farmers in this research.

## 3.1 Barriers

*Operational*

- **Deployment of the term 'the bioeconomy'**

An initial barrier connects to the deployment of the term 'the bioeconomy' in common parlance, policy and instruments linked to payments, schemes and grants. Farmers' perceptions, awareness and understanding of the bioeconomy are fundamental to the development of the bioeconomy and to the process of transitioning. Farmers were invited to explain in their own words what the bioeconomy meant to them. This achieved several highly varied responses including silence. Farmers were subsequently prompted with the below infographic (Government of Ireland, 2026) as a way of understanding the 'bioeconomy in action' as both an economic and sustainable model and were invited to focus on their sustainable agricultural practices ('SAPs') as part of the *Biorefineries*, *Sustainable Agriculture* and *Food Waste* pillars primarily. This was an excellent starting point for discussion.

While on one hand there was 'passive' general acceptance of the bioeconomy (Sadeghhzadeh et al. 2025) evidenced by the farmers in this study, acceptance is not the same as understanding what the bioeconomy is, nor how the bioeconomy may be applied and understood in relation to their individual farm. This may be explained because the bioeconomy is a nascent or emerging entity, or communication of the bioeconomy's application to farmers so far is weak. Furthermore, the bioeconomy's positioning or marketing as something 'new' did not sit right with farmers, especially older farmers who viewed it as '*new wine in old bottles'*, that is, the basic principles of the bioeconomy has been enacted by Irish farmers as matter of course historically and culturally.

- **Capital expenditure costs**

Any new economic or sustainability model such as the bioeconomy proposes, invariably will attract a cost, and this was foremost in farmers' minds. In Ireland, capital expenditure represents the capital farmers spend on acquiring, upgrading, or maintaining physical assets like property, buildings, machinery, and land improvements. Because these investments provide long-term value, they are not treated as immediate day-to-day operating expenses. Several economic barriers were identified in transitioning to the bioeconomy. By way of example, the following vignette provides insight to the financing of a farm-level anaerobic digester to explain the extent of the cost to a farmer and the process of securing external financial support for this farm-level innovation. Farmer 1 had installed an anaerobic digester explained how this was managed financially. The anaerobic digester on his farm was built with a 50% capital grant, provided as part of the recently completed *European Innovation Partnership Programme (EIP AGRI)* (EU Cap Network, 2026) *Small Biogas Demonstration Project (SBDP)* (IrBEA, 2026) set up to develop farm scale biogas plants in Ireland with assistance from the Irish Bioenergy Association (IrBEA). The investment cost €452,000 (ex. VAT) including the cover of the existing overground slurry store and excluding a digestate solid storage shed for which a Targeted Agriculture Modernisation Schemes ('TAMS') (Government of Ireland, 2026) grant has been secured. Other additional costs to include in the overall costs were identified as planning costs, grid connection fee, and environmental assessments. The farmer

investment was €226,000. To put these costs into context – the savings on his annual energy bill amounted to €30,000, so a significant initial financial outlay. The payback period is expected to be 7 to 7.5 years, but this could potentially be shorter if excess renewable electricity can be sold. Given these costs (and potential savings), this option is not available to every farmer. The uptake of anaerobic digestion as technological mitigation strategy is identified in the literature, and the number of anaerobic digestion plants (and subsequently biogas and biomethane production) has increased substantially across Europe with the aim of reducing fossil-derived natural gas dependency (Burg et al. 2018). In Ireland, the uptake for this technology remains very low in comparison to other European countries. This can primarily be associated with the level of uncertainty such systems present to farmers in terms of financial return (O'Connor et al. 2021). Two of the most common feedstocks for on-farm anaerobic digestion systems in Ireland are grass silage and cattle slurry. The production of grass surplus to livestock requirements is a key feedstock for biogas production (Smyth et al. 2009). However, to achieve the successful implementation of on-farm anaerobic digestion systems, proof of its economic viability is imperative to overcome the potential obstacles in the adoption of the technology. While the cost of installation and operationalisation of an anaerobic digester is clearly beyond the means of most farmers, the next largest cost was attributed to construction or adaption of farm buildings, which is within the reach of some farmers.

- **Farm re-construction and adaptation**

Multiple farmers identified how they had re-constructed or had undertaken works to adapt their current building portfolio as a way of maintaining financial stability which included a financial outlay. This was exemplified by Farmer 16, who had built housing for her cattle to maintain their productivity. While the cost of this expansion was not revealed, Teagasc (2026) provide an itemised cost list for a dairy and suckler unit which represents a significant outlay. Both Teagasc and the *Irish Farm Buildings Association* identify planning permission process and approval for a TAMS grant can take from eight months to over a year.

**Table 1: Itemised costs for a dairy and suckler unit**

| Items | Cost per metre € | Dairy unit costs, Figure 1 (€) | Suckler unit costs, Figure 2 (€) |
|---|---|---|---|
| Roof | 110 and 150 per $m^2$ | 130,130 | 60,060 |
| Tank | 130 and 170 per $m^{3*}$ | 103,610 | 44,070 |
| Cubicles and beds | 230 each | 22,700 | |
| Pre-cast cubicles | | 7,670 | |
| Concrete floors | 34 per $m^2$ | 22,610 | 11,016 |
| External walls | 230 per linear m (157/m over tank) | 20,482 | 10,052 |
| Sliding doors | 161 per $m^2$ | 18,998 | 10,964 |
| Feed barriers per bay – straight rail | 143 | 2,288 | |
| Feed barriers per bay – diagonal | 300 | | 1,800 |
| Feed barrier walls | 36 per linear metre | 2,419 | |
| Automatic scrapers | 4,800 per passageway | 19,200 | |
| Pen divisions with drinkers, calving gates etc. | | | 7,273 |
| Water troughs | 495 each | 1,980 | |
| Electrical works | 350 per bay | 5,600 | 2,100 |
| Cubicle mats | 80 each | 9,280 | |
| Cattle crush and holding pens (including concrete) | | | 9,260 |
| Miscellaneous | | 12,240 | 8,000 |
| Total | | 377,147 | 164,595 |
| Number of animals | | 116 | 50 |
| Cost per animal | | 3,140 | 3,252 |
| Roof and tank (% of total) | | 62% | 63% |

**Slatted tank costs vary depending on size, whether double or single tank so €130 and €170 per cubic metre is used for the dairy and suckler tanks respectively. Costings based on available information March 2025*

- **Machinery investment and rental costs**

Machinery investment and rental costs presented another significant barrier to farmers. To transition to the bioeconomy, Farmer 17, identified how increased costs for purchasing or renting machinery was a prohibitive factor. He emphasized that *"machinery is just shocking"* with costs making:

> *"reinvestment and changing direction a lot more difficult, because you need so much capital to get up and running, so you have to tread carefully. You can't make a mistake, because it'll be high stakes for the amount of money you're spending."*

This element of financial risk linked to capital expenditure was re-iterated by Farmer 3, who identified the significance and reality of small margin gains in developing new innovations that needed the acquisition or hire of new machinery:

> *"...the margins are small enough that we can't afford to take massive risks and go broke trying to find a better way to do something."*

Until this point the value of the farm machinery industry in Ireland was not delineated. Recently the industry body for farm machinery, the *Farm Tractor & Machinery Trade Association*, published their first economic report (Farm Tractor and Machinery Trade Association, 2026) which identified the current or planned investment plans of their members which they describe as 'expansionary' in the €300,000+ region. While most farmers in this study would not fall in the category of being able to easily purchase machinery, the costs of renting machinery are significant with costs for renting a tractor (with attachments) amounting to €5,000 per annum or excluding VAT and fuel (Templetuohy Farm Machinery, 2026). Prices depend heavily on the machine's horsepower, the rental duration, and the time of year (e.g., higher demand during silage season). Given these costs of purchasing and/or renting a fleet of machinery has clear impacts on a farmers' capacity to 'scale up and out' without support.

- **Scaling 'up and out'**

In the bioeconomy, scaling up means increasing production capacity for bio-based products. Scaling out refers to the replication of these localised, circular production models across different regions to maximize regional resources. Connecting to farmers in this study – Farmer 21, identifies asset acquisition while scaling up, recognising that although this is desirable, it sometimes does not make sense from a financial perspective. He explained scale limitations in the following way:

*"I'm only dealing with... 20 or 30 acres of spring barley... I could go away and change one field at a time, but... I can't have all that infrastructure or machinery sitting inside the farmyard to justify doing that...the financial side of it is one of the main barriers, I think …just on a smaller enterprise."*

Farmer 18, echoed this:

*"I couldn't actually afford to do it myself. You know, I mean, the scale is too small to invest in the machinery."*

Other lesser but still significant financial costs included testing and certification costs.

- **Testing and certification costs**

Farmer 17 identified testing and certification costs in relation to organic poultry production. He identified poultry litter testing as expensive and unreliable as standards vary between lab testing facilities.

*"getting it tested... I could go to two different labs; I'll get two different results with the same sample... those samples aren't cheap."*

He also faced certification barriers on grounds of repeated certification costs:

"*if I want to process straw for chicken bedding myself, I would have to get that board BS certified, and with the investment, and getting it certified every year, I'd be looking at a big financial impact."*

Securing finance in the form of grants to initialise innovations also proved difficult and this was evidenced by grant processing delays, the high administration burden and potential arbitrary desk rejections.

- **Grant processing delays, administration burden, arbitrary desk rejections**

Grant processing delays were identified as an acute problem for farmers, and this is exemplified by Farmer 22's experience of applying for a grant with a long processing time:

> *"I applied for a grant for a slurry tank last April. And the first I heard back was November. I had builders… I had everything ready for August."*

This seven-month delay meant builders and contractors waiting without work, and when approval finally came, the farmer received a *'seven days to reply'* letter. Farmer 23 had similarly applied for a solar grant and experienced the equivalent issues; his application was approved but not paid which created cash flow problems in completing the work. It must be noted these delays occur while construction costs escalate, potentially exceeding grant amounts by the time approval arrives. In addition, farmers noted the disproportionate effort required to complete small grant applications compared to larger grant applications with Farmer 24, identifying that some agricultural consultants now refuse to administer smaller grant applications because of the paperwork and the impact on delivering innovations on this farm:

> *"the same amount of paperwork, you have the same amount of 'bull', but you're just not getting the reward out of it. But it's those small changes… you can't make those small changes then… it's nearly an all or nothing."*

This example shows how the system makes it difficult for farmers to attempt smaller incremental improvements because of the administrative burden involved. It also

forces farmers into large-scale innovations (if they can afford it) or abstain from making an application for a grant. There were also issues with seemingly arbitrary desk paperwork rejections by the unit assessing applications. This was exemplified by an invoice being returned as ‘paid’ but not dated:

> *"because it wasn't dated, right? It was marked paid, but it wasn't dated. It was marked paid. Stupid stuff."*

This ‘box-ticking approach’ ignores the merits of the application in favour of perfection. The example above could have been easily solved with a telephone call instead the rejection of this application for an easily solved issue increased the processing time for both farmer and agricultural advisors alike. These difficulties created a situation where farmers were prepared to ‘by-pass the system’ to progress their farm-level innovations, in some instances without the financial support that was available but inaccessible to them. Multiple farmers concluded that building or purchasing items without grants may be more practical despite higher costs involved. Farmer 28 noted:

> *"Several fellas told me last year, you should have gone away and built a tank, and forget about the grant, and forget about planning, forget about all that. And in hindsight, they're right. Because now the price of everything has gone up more than we're going to get in the grant."*

Farmer 30 shared similar ‘thinking’; explaining how the criteria for some grant opportunities were difficult to achieve meant he progressed without further attempts to secure a grant:

> *"We didn't meet the criteria for the solar now twice, and I'm just turning around, and my son, who's an electrician, is involved in the solar business now, and his company came back to us with an excellent quote, and I'm just*

*saying to my wife, to hell with it. I might just not bother with any of the grants, and go ahead …and just go ahead and do it."*

This highlights a key dilemma for farmers, grants are substantial enough to be essential for large projects like slurry storage, but the process is so multi-layered, it is difficult to navigate, that farmers forgo making initial or repeated applications.

- **Carbon accounting**

The 'formula' for carbon accounting was identified as a barrier because it was deemed unfair. Farmer 28 highlighted fundamental unfairness inherent in current farm accounting:

*"At the moment your carbon is linked to whether you're using protected urea or not, but it's not linked—you could have 40 acres of forestry and you could have every shed in the place covered with solar panels and you'll get no credit."*

This creates a situation where farmers making substantial investments in carbon sequestration and renewable energy receive no recognition in carbon accounting. He described meeting a German intensive dairy farmer who claimed carbon-negative status. He explained the difference in her situation compared to his own:

"*she had trees, she was getting credit for that. We're not. She had solar panels, she was getting credit for that. We're not. So, if it was a fair playing field… they're asking us to play a game that they've rigged the rules."*

All her cows were housed indoors, yet the carbon accounting system credited her for trees and solar while Irish farmers grazing outdoors receive no credit for similar investments. This was echoed by Farmer 16 who pointed out that a similar discrepancy in the attribution of credits:

*"the solar panel companies get the credits for the carbon, and we [the farmers] pay for them."*

Farmers invest in renewable energy infrastructure but the carbon credits flow to installation companies rather than the farm operations using the clean energy. A similar type of inequity was also experienced by dairy farmers in the marketplace.

- **Lack of marketplace differentiation for milk production**

This barrier linked to the use or non-use of chemicals in grassland for milk-production and how this is managed by milk and dairy processing facilities, Farmer 29 acknowledged:

"*I've no issue doing it [sustainable milk production], but the problem is the other farmers supplying milk who are putting out 250 kilos of nitrogen, and my milk goes into the same processing plants as theirs, so there's no incentive*."

This creates a situation where farmers who do not use chemicals do not necessarily receive a price premium despite the additional effort and risk. This was re-iterated by Farmer 27:

"*The reward for nature-based… for organic milk…for anything like that, the level of payment that's actually required, the reward for it …it's not there. Unfortunately, you hear of how many organic dairy farmers are still selling their milk at a conventional price, because there's no market for it*."

This inequity could also be linked to the dominance of intensive farming currently in Ireland.

- **Intensive farming v farming with nature**

Farmer 30 identified the reality of farming in Ireland with its intensive blueprint model thoroughly embedded:

> "*…there is a blueprint model out there…the chemical-based one, whether we like it or not, that is very simple and easy to follow. Whereas if you're farming with nature, you have to be a bit more 'tuned in', a bit more inclined to 'roll with the punches' a bit. There is a good bit of learning needed."*

This creates an economic deterrent for those farmers who may be keen to adopt sustainable agricultural practices. In addition to this, those farmers must acquire more knowledge to exploit the breadth of sustainable agricultural practices. Whilst acquiring knowledge may seem straightforward, this was not experienced by farmers who attempted to increase their knowledge formally.

- **Difficulty acquiring appropriate training for Irish conditions and 'expert' advice**

Securing appropriate training in an Irish context proved difficult to acquire. Farmer 28 completed a recent course provided by an American expert, following which he attempted 45–90-day paddock rest periods, which proved disastrous in Irish conditions where grass had "*no nutrition left*" after such extended periods. He spoke about the trainer:

> *"He's coming from a place where desertification is an issue, …desertification is not going to happen anytime soon. So what he's talking about is very good in South Dakota and places like that, but in Ireland, we have a totally unique ecosystem."*

After completing a UK-based course, he also sought information on conducting trials in intensive grassland systems at home but found course providers were on the 'hard sell', knowing there was a captive market and a high level of interest on the ground among farmers:

> "…*they just seemed to be interested in selling courses and speaking to the converted, there's an awful lot of people out there who have a huge interest"*

This disconnect between course providers and practical implementation support frustrated farmers seeking to apply new knowledge to their own farm. Added to which, this proactive approach in acquiring training by farmers was contrasted with public narratives about them.

*Social*

- **The farmer 'scapegoat', farmers' tacit knowledge, the non-farmer 'experts'**

The current farmer identity operating in public narrative was problematic for farmers in which they saw their knowledge disregarded and their profession 'scapegoated' for their role in the climate crisis:

> *"It doesn't really matter what you think if you don't have a farm, or unless you're involved with farmers or helping farmers … there's a lot of people who just want to go and criticize."*

In addition, Farmer 16 observed that farmer's tacit knowledge is often ignored:

*"As farmers, we seem to be much more aware of the climate crisis, the water quality crisis, biodiversity crisis, than the general public, and I think that's quite ironic that we tend to get blamed for a lot of things, and yet we're the ones that are actually aware of these things and working hard towards improving things like water quality."*

Farmer 28 connected this to ungrounded expert advice from those who are not farmers:

*"There's an awful lot of people giving advice, telling us how to do our job, who can't do our job."*

On the personal level, the farming family presented some barriers to transitioning to the bioeconomy.

*Familial*

- **Family dynamics, intergenerational relations, and family life stage**

Farming with family members requires agreement before trying new practices emerged as a significant barrier, this pays attention to the social and personal context associated with transitioning to the bioeconomy. Farmer 21 explained:

"*I work with my father as well, and you can't just go and do things without being in agreement. So, when there's something new he's not convinced about, that's also a barrier. You have to be 'pulling together on the one wavelength'*."

He elaborated on the challenge when new innovations on the farm were not successful:

"*when they don't work, it's even worse. So, it's even harder to get around [them] when you know that they might work or will work, and it just didn't work once*."

Farmer 3 tied decision making to intergenerational relations and the impact the elders have on his current practices and his ability to forge ahead even with their approval:

*"I started off farming with my father and my uncle, and my father is retired... if I can run it by my uncle and my father, and they don't think it's a terrible idea, I kind of tend to think maybe it's not a bad idea at all, and sometimes I run it by them, and they think it's a terrible idea, and I'll go and I'll make all the mistakes in the world to prove that I'm right."*

Farmer 17, provided a broader context on family farm dynamics:

*"your tradition, and the place you've come from, and the things you're proud of, and your makeup, and what your mother and father taught you, and the way your grandparents farmed, and you have to tread that line of having massive respect for where you came from. But also, if it's not going your way, it's not going anywhere, because one of the biggest problems we have in farming is succession."*

He emphasized the emotional dimension of implementing innovations, which is important not to ignore, and which has been overlooked in the literature:

*"any time I've a row with the ole lad it's because we both care very much deeply about what we're talking [about]"*

Farmer 16 also highlighted how the family life stage can constrain financial risk-taking in her consideration of adopting organic farming:

> "*If you make a big change into organic dairying or something, there's that uncertainty about our income. And you don't want that uncertainty at this point in your life, do you know? With kids growing up."*

While some of these barriers are felt deeply by farmers, they were open to identifying some pathways that would ease their transition into the bioeconomy more fully.

### 4.2 Pathways to the development of the Irish bioeconomy

Farmers developed a set of transition pathways linked to the lived experience as to how they believed the emerging bioeconomy could be realised for them. A starting point was how the bioeconomy could be more clearly defined for the agri-food sector.

- **Co-created place-based definition for the Irish bioeconomy**

The deployment of the term 'the bioeconomy' is identified as a barrier because of lack of clarification as to what it means – one way in which this could be addressed is clearer communication of the benefits of the bioeconomy for farmers. In addition, focus must be given to the fact that in a lot of situations, farmers are already adopting circular bioeconomy practices without labelling their practice(s) as such. This finding is evidenced in the Western Macedonia region of Greece (an area much smaller that Ireland) where farmers identified their activities and were then asked how they would like to be 'trained up' in the bioeconomy (Papadopoulo et al. 2023). The authors then classified the farmers into clusters which they titled 'engaged', 'restricted' and 'partially engaged'. Orienting communication from this baseline and typology may be useful in the Irish context, before agreeing an appropriate agri-bioeconomy definition that is 'co-created and place based' (Moore-Cherry et al. 2025).

- **Adoption of six-week application processing standard for grants, payments and schemes**

Adopting Scotland's six-week maximum processing time for processing grants, payments and schemes with automatic approval if deadline is missed would force government efficiency and provide certainty for planning. This removes the current situation where farmers wait months for responses, missing construction windows and facing cost escalation. This automatic approval after six weeks forces government efficiency and provides certainty for planning. In addition, small grants need simplified administration proportionate to their value, rather than identical paperwork to large grants. This would enable incremental improvements rather than forcing all-or-nothing large-scale changes.

- **Adoption of 'farm clustering' and 'one-stop-shop' management**

The Scottish farm clustering model ('Farmer Cluster Connections') (Bohnet et al., 2026; Nichols et al., 2025) was identified by several farmers. This model locates a group of like-minded farmers in a region who then employ a farm cluster manager to identify schemes, navigate bureaucracy, and coordinate implementation. This manager acts as a one-stop shop, charging each farmer approximately £300 annually to handle all scheme applications and coordination. The model worked across diverse farm types including intensive dairy, commercial fodder production, and pedigree suckler breeders, with the manager identifying opportunities relevant to each operation.

- **Results-based payment and schemes**

Farmers identified the need for results-based payments and schemes, for example linking milk price directly to carbon output metrics (nitrogen use efficiency). This finding corroborates the findings of the DAFM funded *FARMCredit Project* (2023-2025) (Knapp et al., 2026) who identify that increased private sector financing is needed to fund climate and biodiversity action on farms. The authors identify that farmers are receptive to sustainability financing through (carbon) insetting. However, improved standards, data collection, and verification are needed in the agri-food industry. They

also identify the administrative burden of participation in insetting is a key concern for farmers. Whilst being results-based, farmers also requested for payments, schemes and grants to be index-linked.

- **Index-linked and guaranteed payments**

Farmers advocated for index-linked support payments to prevent real-value erosion and maintain long-term effectiveness. In addition, they suggested guaranteed payments for minimum 10 years with clear commitment to enable intensive farmers to restructure systems without risk to their incomes.

- **Application of fair carbon accounting**

Accurate quantification of agricultural carbon outcomes is the basis for achieving emission reductions for agriculture, but existing approaches for measuring carbon outcomes (including direct measurements, emission factors, and process-based modeling) fall short of achieving the required accuracy and scalability necessary to support credible, verifiable, and cost-effective measurement and improvement of these carbon outcomes (Guan et al. 2023). Farmers identified how the carbon accounting system must be consistent in how it treats inputs and outputs across all farm inputs, not arbitrarily counting some as "*counterparts used*" and others as "*counterparts produced*." This finding supports other findings internationally where carbon accounting is mis-aligned and has an implication for policy creation and development. Guan et al. (2023) provide a foundational and scalable framework to quantify field-level carbon outcomes for farmland, which is based on what they term 'the holistic carbon balance of the agroecosystem'. Writing more recently, Burkitbayeva et al. (2026) note the urgency for the development of international accounting methodologies for greenhouse gas emissions in agriculture and emphasize the necessity of reliable farm-level measurement and proposes a conceptual framework to unify disparate embedded emissions accounting standards across agricultural supply chains. In the context of Ireland, Matthews and O'Neill (2025) link this issue to the reliance of the Government on subsidies and the need for a longer-term view, they argue for the introduction of 'emissions pricing' as a complement to subsidies to accelerate decarbonisation.

- **Wool re-classification, processing and circularity**

Raw sheep wool in the European Union is heavily impacted by strict animal byproduct rules (EC 1069/2009), which classify healthy fleece under rigid waste-handling and disease-prevention categories, leading to plunging market prices, high disposal costs, and up to 90% of local wool being buried or burned (International Wool Textile Organisation, 2026; Murphy, 2025). Sheep farmers in this research identified a clear pathway by re-locating wool from a Category 3 waste to resource, removing regulatory barriers to product development and market growth. In addition, support on-farm and local processing equipment (rather than waiting for centralized scouring infrastructure).

- **Farm-matching and grazing facilitation**

Farmers requested that digital platforms be established for matching farms with surplus slurry/manure to farms with capacity to import, facilitating nutrient circulation and environmental compliance. In addition, farmers requested a grazing facilitation service connecting livestock farmers with tillage/lightly-stocked farms to enable nutrient return through grazing rather than silage sales.

**Next: Report 3 'Transferable Lessons for Role Model Farming' (for testing in Co-Design Laboratories)**

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