An Roinn Gnó,
Fiontar agus Nuálaíochta
Department of Business,
Enterprise and Innovation

Realising the opportunities for enterprise in the bioeconomy and circular economy in Ireland

Background Paper

Section 1. Introduction

Background

This report aims to ensure that the Department of Business, Enterprise and Innovation's response to issues arising from the transition to a low carbon circular economy and bioeconomy is informed by a clear evidence-based understanding of the potential enterprise opportunities.

The report has been developed in the context of policy developments within DBEI, including the Refresh of Research Prioritisation, Innovation 2020, Enterprise 2025, and Future Jobs Ireland 2019.

The *Refresh of Research Priority Areas 2018-2023* identifies six themes with which the majority of competitively awarded public investment in research will be aligned. A number of these are of direct relevance to the bioeconomy and circular economy, including the priority themes 'Food', 'Manufacturing and Materials', and 'Energy, Climate Action and Sustainability'. This latter theme was introduced in 2018 as an outcome of the refresh process in response to a marked increase in importance of the challenges of climate change and sustainability over recent years, as evidenced by significant policy developments at national and international level.

Ireland's national innovation strategy *Innovation 2020* highlights the need for innovation to help address the grand challenges of our time, including climate change, resource depletion, environmental degradation and pollution. The challenges informing *Innovation 2020* are therefore the same as those driving the development of both the bioeconomy and the circular economy in Ireland. *Innovation 2020* acknowledges the need for enterprises to innovate both to find solutions to these challenges, while at the same time seizing on the opportunities that such disruptive innovation presents.

This message is further reinforced in *Enterprise 2025 Renewed* which sets out the challenges and opportunities presented to enterprise in Ireland due to a rapidly changing global environment. It sets out Ireland's enterprise strategy as one in which we aim to sustain what we have in the immediate term; transform our enterprise base for longer-term resilience; and build on our strengths to be successful in international trade while managing potential vulnerabilities. The development of the circular economy and the bioeconomy in Ireland have the potential to be important drivers in the renewal of Ireland's enterprise base, as envisaged in *Enterprise 2025 Renewed*.

Future Jobs Ireland 2019 contains the ambition to leverage Ireland's natural resources, enterprise strengths and innovative capacity to be a global leader in the circular and bioeconomy. It includes actions related to overcoming regulatory barriers, raising awareness, developing infrastructure and scoping of biomass resources and business support services.

The current report has also been developed in the context of the government's *National Mitigation Plan* and, in particular, a recommendation by the National Competitiveness Council to undertake an assessment from an enterprise perspective of the *National Mitigation Plan* to evaluate green economy opportunities, as well as potential negative impacts on the enterprise sector.

OBJECTIVES

This report has four objectives:

1. To describe clearly what the circular economy and bioeconomy are
2. To outline the breadth of enterprise activities already ongoing in these areas
3. To outline the future potential for enterprises in these areas, and
4. To provide guidance for policy to ensure that enterprises in Ireland engage fully with the opportunities presented by the development of the circular economy and bioeconomy here.

THE BIOECONOMY AND CIRCULAR ECONOMY

In 2018 the Government published the first *National Policy Statement on the Bioeconomy* which highlights the potential of the bioeconomy in promoting the more efficient use of renewable resources while supporting economic development and employment in rural Ireland.

A High-Level Bioeconomy Implementation Group (BIG) has been established to address key actions for the future success of the bioeconomy in Ireland. DBEI is playing an active role in developing the strategic direction of the bioeconomy through participation on BIG. The BIG presented its first report to Government in Q2 2019.

The BIG aims to progress the development of the bioeconomy in Ireland, through focused actions including:

- Strengthening policy coherence across government with regard to the bioeconomy
- Establishing a network of commercial entities and public bodies to inform the development of the bioeconomy
- De-risking engagement in innovation and EU funding opportunities
- Encouraging the translation of research into real world applications through promoting collaboration between research institutions (academia) and industry, including the use of pilots/demonstrators, and
- Addressing barriers to the minimisation and valorisation of organic wastes.

At the same time, there is increasing recognition of the potential benefits for economies and societies of moving away from a 'make-use-dispose' model of production and consumption towards adopting a circular economy, in which we keep resources in use for as long as possible. A fully circular economy requires a systemic and transformative approach to production and

consumption that effectively designs out waste and keeps materials and resulting products in use for as long as possible.

The circular economy is closely linked to the bioeconomy. Table 1 outlines some of these similarities. In this report, in the interest of clarity, the bioeconomy and circular economy will be described separately.

Table 1: Common Issues and Challenges regarding the Bioeconomy and the Circular Economy
Both the circular economy and the bioeconomy will make waste a valuable resource.
The transition to both a circular economy and a bioeconomy could bring considerable environmental benefits including reduced emissions, reduced depletion of natural resources and reduced pollution.
The transition to both a circular economy and a bioeconomy could bring significant economic benefits including job creation, increased competitiveness and increased regional and inclusive development.
The development of the bioeconomy and the circular economy are both taking place at a global level. As a small, open economy within the EU, Ireland's move towards both a circular economy and a bioeconomy will continue to be shaped both by EU policy and developments internationally.
The full potential of both the circular economy and the bioeconomy for Ireland is still in the process of being identified.
Progressing both the circular economy and the bioeconomy present governance challenges, since they are both multilevel and cross-sectoral, and have social, economic and environmental dimensions. Strong central policy support, based on a holistic and strategic policy approach, will be required to progress both transitions.
EU countries are developing both circular economy and bioeconomy strategies. A key challenge is to align these policies effectively.
Intrinsic to both the circular economy and the bioeconomy is creating connections and cooperation. Both require close collaboration across and within sectors and their supply chains and involve multiple stakeholders in private and public sectors, both nationally and internationally. Given Ireland's small scale, the transitions will also require forging links with other countries on research and technology development and adoption.
Civil society has a key role to play in transitioning to the circular economy and the bioeconomy. Increased public understanding of the purpose and direction of the circular economy and the bioeconomy will be fundamental in shaping how they evolve.

The meaning and nature of both the circular economy and the bioeconomy need to be understood more widely among policymakers, researchers, enterprises and wider society.

MARKET OPPORTUNITIES

The diversity and scale of the potential opportunities for enterprises in Ireland can be gauged from the market opportunities identified as part of the *Refresh of Research Prioritisation* in 2017. The following global market opportunities across some of the sectors relevant to the bioeconomy and circular economy were identified in this report:

- The **Nutraceuticals and Functional Foods** market consists of food and nutrition supplements, specialty nutrients and infant formula. The market has a current estimated value of US$190.7 billion, and is estimated to have a value of US$279 billion by 2021
- The global **Dairy Products** market was valued at US$336 billion in 2014 and is expected to reach US$442 billion by 2019. The Irish Dairy Products exports market has an estimated value of €3.38 billion with access to over 130 markets
- **Meat Products** account for over 40% of Ireland's gross agricultural output, and is currently estimated to be worth €5.3 billion
- The **Biotechnology** market opportunity has a high degree of exports from Ireland, with an estimated value of €22.72 billion at the current time
- The **Biorefining and Bioconversion** market consists of various forms of agricultural and forest biorefining, including feedstock, products and segment (energy, chemicals, botanicals and fuels). The global Biorefining and Bioconversion market was estimated to be worth US$659 billion in 2016
- **Smart Construction** consists of commercial modular buildings (both permanent and relocatable) and residential modular buildings. The global Smart Construction market had an estimated value of US$131.6 billion in 2016 and is estimated to have a value of US$177.1 billion by 2021
- **Low Carbon Construction** consists of residential, commercial and industrial buildings designed to release little or no carbon over their lifetimes, and their associated materials and services. The Global Green Construction (GGC) market is a significant component of the Low Carbon Construction market and had an estimated value of US$216.8 billion in 2016, estimated to reach $453.1 billion by 2022.

1.1 Overview of the Bioeconomy

IRISH GOVERNMENT'S STRATEGIC OBJECTIVES FOR THE BIOECONOMY

The National Policy Statement on the Bioeconomy states that in seeking to expand the bioeconomy, Government has several strategic policy objectives in mind:

- *A sustainable economy and society* - Growing the bioeconomy can put Ireland's economy on a more sustainable footing by encouraging the efficient use and re-use of resources and materials.
- *Decarbonisation of the economy* - the bioeconomy can play a part in lowering greenhouse gas emissions through, for example, the development of innovative practices and processes that can improve the efficiency in agriculture and forestry production systems.
- *Jobs and Competitiveness* - the bioeconomy can foster employment as many of the inputs for the bioeconomy are sourced nationally, so its development has a higher multiplier effect compared to other areas of the economy that are more reliant on imports. In this context, it is worth noting that as the agri-food and marine sector faces considerable uncertainties due to the prospect of Brexit, growing the bioeconomy represents an opportunity for this sector to diversify and reduce the risks confronting it.
- *Regional Prosperity* - one of the advantages of the bioeconomy is that many of the businesses rooted in it are located in rural and coastal areas. Helping the bioeconomy to grow can assist in halting rural decline.

An important term in the bioeconomy is biomass. Biomass refers to material of plant or animal origin.

POLICY DRIVERS

The importance of the bioeconomy is being increasingly recognised internationally and nationally. The European Union published its bioeconomy strategy in 2012 which has amongst its principal goals to assist in climate change adaptation and the creation of jobs. It has been estimated that the direct research funding associated with the strategy under Horizon 2020 could help generate 130,000 additional jobs and €45 billion in added value by 2025. The strategy is structured around three pillars: investments in research, innovation and skills; enhancement of markets and competitiveness; and reinforced policy co-ordination and stakeholder engagement.

The EU bioeconomy strategy is supported by two EU research and innovation funding programmes, Horizon 2020 Societal Challenge 2 (SC-2) and the Bio-based Industries Joint Undertaking (BBI JU). The latter is a €3.7 billion public private partnership which focuses on turning biological resources, including terrestrial and marine resources as well as residues and wastes, into greener everyday products through the development, de-risking and scaling up of innovative technologies and bio-refineries. The establishment of the BBI JU is designed to give a

strong political signal to industry by providing a stable long-term funding framework that allows for strategic planning. This stability is vital in leveraging long-term investments from the private sector, in particular for demonstration and large-scale deployment activities.

The EU's Strategy was updated in October 2018. The new strategy includes a €100 million Circular Bioeconomy Thematic Investment Platform to bring bio-based innovations closer to the market and de-risk private investments in sustainable solutions and facilitate the development of new sustainable bio-refineries across Europe. The update proposes a three-tiered action plan to: strengthen and scale up the bio-based sectors, unlock investments and markets; deploy local bioeconomies rapidly across the whole of Europe; and understand the ecological boundaries of the bioeconomy.

ENTERPRISE OPPORTUNITIES AND CHALLENGES IN THE BIOECONOMY

Opportunities

Ireland enjoys some important comparative advantages in relation to the bioeconomy. Ireland has a significant agricultural footprint with about two thirds of its land devoted to agricultural use. Agri-food is the largest indigenous business and accounts for 5.7% of our GDP. Approximately 10.7% of Ireland is under forests which produce 3.2 million cubic metres of material each year and this is forecasted to increase to 8 million by 2035. Ireland has one of the largest seabed territories in Europe which is about 10 times its landmass with a reservoir of genetic material with natural product potential. In 2016, Ireland's ocean economy had a turnover of €5.7 billion. The direct economic value was worth €1.8 billion or approximately 0.9% of GDP.[1]

Ireland has also grown its bio-pharmaceutical sector rapidly with the sector producing €39bn in exports. Current enterprise activity is being driven mainly by Ireland's nature resources, rather than by the existing enterprise base, but there may be potential for increased alignment between the biopharma sector and current and future bioeconomy actors.

With 80% of the agri-food sector based in rural Ireland, there is potential for the bioeconomy to boost employment in regions. *The Action Plan for Rural Development 2017* underlines how the bioeconomy can contribute to decarbonisation, sustainable growth and job creation in the agricultural, industrial and technological sectors in rural areas.

In addition, a scoping exercise was conducted with Departments and agencies as part of preparation of *National Strategy Statement on the Bioeconomy* to identify the current/potential activities in the bioeconomy area. The primary focus of measures identified was on rural development, the valorisation of marine discard and agricultural waste, and the production of

[1] Ireland's Ocean Economy, Socio-Economic Marine Research Unit (SEMRU) at NUI Galway, 2017

bio-energy from biomass/biogas. This report aims to provide further detail on the range and scale of enterprise opportunities in the bioeconomy.

Challenges

Significant challenges need to be overcome to develop the bioeconomy in Ireland. The *National Statement on the Bioeconomy* highlights the following challenges involved:

- The need for investment for building necessary infrastructure
- Need to develop greater policy coherence
- Developing an appropriate regulatory regime
- Encouraging private investment
- Stimulating market demand including public acceptance of bioproducts

The Bio-Éire project highlighted a number of additional concerns, namely: sourcing biomass at sufficient scale, international competition, economic/ technological feasibility, environmental sustainability, the prevalence of robust supply chains, industry fragmentation, and competition with food production.

MAJOR POLICY INTERVENTIONS TO DATE

A number of policy interventions are already underway to support the development of the bioeconomy.

The Government is providing €4.6 million in financial support through Enterprise Ireland's Regional Economic Development Fund for the establishment of a bioeconomy innovation and piloting facility at Lisheen, Co. Tipperary. The facility will enable industry, entrepreneurs and researchers to scale technologies that convert Ireland's natural resources to products of high value for use in a wide variety of sectors including food ingredients, feed ingredients, pharmaceuticals, natural chemicals, biodegradable plastics and more.

Another significant initiative has been majority funding by government through Science Foundation Ireland of €14.2 million for the Beacon Bioeconomy Research Centre which will explore how to convert biomass resources and the residues produced during food production into higher value products. MaREI, the marine and renewable energy research, development and innovation Centre, is also supported by Science Foundation Ireland. The MaREI Centre conducts fundamental scientific research relating to marine and renewable energy applications, including bioenergy, and enables the development and testing of technology through to the construction of demonstration systems.

Over the past several years, the Department of Agriculture, Food and the Marine has also funded a number of collaborative academic-led bioeconomy related research projects. The Bio-Éire research project, led by Teagasc, focused on identifying and prioritising interlinking cross-sectoral value chains in the bioeconomy. Value chains with significant short-term potential were

identified, including the use of dairy side streams for new food products and the use of agricultural / food waste for bio-energy production.

Other significant developments include the establishment of the Irish Bioeconomy Foundation to bring together relevant stakeholders with an interest in establishing a National Bioeconomy Hub to be co-located with the Bioeconomy innovation and piloting facility at Lisheen, Co. Tipperary. In Monaghan, BioMarine Ingredients have established Ireland's first pilot scale biorefinery plant. In addition, a Marine Innovation Park, Páirc Na Mara, has been established in Connemara to drive the sustainable growth of the marine economy.

1.2 Overview of the Circular Economy

DEFINITION OF THE CIRCULAR ECONOMY

The Circular Economy arises from the increasing recognition of the potential benefits for economies and societies of moving away from a 'make-use-dispose' model towards adopting circular economy principles to maximise resource efficiency and environmental protection.

A fully circular economy requires a systemic and transformative approach to production and consumption that effectively designs out waste and keeps materials and resulting products in use for as long as possible. It represents a fundamental shift in the relationship between production and consumption and natural resources.

The circular economy is closely linked to the bioeconomy. Many bio-based materials are renewable, biodegradable and compostable and can become the basis for important circularity in an economy. The circular economy, however, also encompasses the application of circular economy principles to non-biological resources, including manufacturing and consumption of goods and services.

POLICY DRIVERS

The circular economy has become a policy priority of the European Commission in recent years. The EU Circular Economy Package is at an advanced stage, following the publication of the European Commission's plan *Closing the Loop: An EU Action Plan for the Circular Economy*.

The *Closing the Loop Action Plan* contains 54 measures covering a range of areas concerning consumption and production processes and products across priority sectors including plastics, food waste, critical raw materials, biomass and bio-based products, and construction and demolition. It includes financial incentives for research and innovative policy measures using structural funds (€5.5bn) and Horizon 2020 (€650mn). This is combined with a suite of regulatory and legislative actions aimed at changes to product design, production processes, waste management, consumption, procurement, boosting the market and monitoring.

The European Commission has developed mandatory product design and marking requirements to make it easier and safer to dismantle, reuse and recycle electronic displays (e.g. computer

monitors, televisions and electronic display integrated in other products). In addition, the European standardisation organisations are working to develop generic standards on the durability, reusability and recyclability of certain products.

On the regulatory side, extended producer responsibility (EPR) seeks to achieve a reduction in the environmental impact of products, throughout their lifespan, from production through end of life. It involves a shift in responsibility (administratively, financially or physically) from governments or municipalities to producers. It is being used for packing, WEEE, cars and other products within the EU. France and Japan have developed it further. France has 14 mandatory EPR schemes for furniture, tyres and infectious healthcare waste. Japan requires manufacturers to use recycled materials and reusable parts in new products. Ireland has a Producer Responsibility Initiative (PRI) for tyres and is now introducing a more comprehensive compliance scheme.

ENTERPRISE OPPORTUNITIES AND CHALLENGES IN THE CIRCULAR ECONOMY

The socio-economic value of a circular economy lies in reduction in scarce raw materials and natural resources, resource efficiency and job creation. The NESC report *Moving Towards the Circular Economy in Ireland*, the most comprehensive study of the Circular Economy in Ireland to date, points to the potential for job growth and enterprise development. UK and Dutch research points to approximately 50,000 jobs that could be created from a transition to a circular economy in their respective countries.[2] One Irish study estimated that 5,000 new jobs could be created through recycling materials such as plastics, paper, glass and WEEE, with a potential added GDP value of €1.65bn. Such jobs would range from low to high-skilled, from sorting recyclables to eco-design, and could be an important stimulus for employment, including in rural areas and areas of economic and social deprivation. A Green Alliance study shows that circular economy activities create jobs in occupations and regions with persistently high unemployment rates and contribute to reducing structural unemployment. Research indicates that the recovery, reuse and recycling of materials such as plastics and food waste would also bring substantial savings to businesses and consumers.

The circular economy presents challenges and opportunities for manufacturing practices. The ‘use, reuse’ model at the heart of the circular economy requires a shift in how conventional product design, manufacturing and retail is configured. Critically, the emphasis has to shift to product design (eco-design) where 80 per cent of a product’s environmental impact is determined. There has been slow progress globally to date, however, in making the shift across supply chains, given the level of systemic change required.

In June 2016, the European Commission published results from a survey that explored SME activities in relation to the circular economy. This is a summary of the 400 responses from Irish

[2] Moving Towards the Circular Economy in Ireland, National Economic and Social Council, October 2017

SMEs. The survey indicated that 73% of European SMEs have invested in the transition to a more circular model for their businesses over the past three years. Of the actions taken by Irish SMEs, waste is the most active area of investment. Among Irish SMEs there is low awareness of financial incentives for the circular economy and therefore most of the actions undertaken were self-financed. Also, few SMEs considered it easy to access information on the circular economy.

MAJOR POLICY INTERVENTIONS TO DATE

Ireland's *Draft National Planning Framework, Ireland 2040: Our Plan*, includes a vision for Ireland to have a 'capacity for sustainable self-reliance based on a strong circular economy and significant progress towards a low-carbon, climate-resilient society'. Ireland, alongside other member states, is monitoring EU legislative developments and the implementation of the *Closing the Loop Action Plan*.

A recent report by the European Environment and Sustainable Development Councils, of which NESC is a member, outlined the state of play of circular economy activity in 10 EU countries. It outlines the varied approaches taken, with Denmark and the Netherlands setting out long-term, high-level, focused strategies on the circular economy to 2030 and 2050 respectively, while Germany and Belgium have adopted strategies with more immediate timelines. Ireland and Portugal are noted as the two countries in the study that have yet to adopt a dedicated strategy.

PRODUCTIVITY AND THE BIOECONOMY AND CIRCULAR ECONOMY

Productivity gains lie at the heart of the bioeconomy and the circular economy. The enhancement of the productivity of agricultural systems, including emerging technologies such as biotechnology, precision farming, and eco-agriculture will be required in order to meet growing demand from agricultural systems without drastically increasing their environmental footprint. The biorefining of high value products from biomass, such as biochemicals and biomaterials, also marks the creation of new high productivity activities within the economy.

While conventional productivity gains are achieved by raising labour productivity or through the adoption of technology, when it comes to the circular economy, the issue of improving resource productivity is central. The growth of resource productivity through circular economy practices generates primary-resource benefits. It is estimated that Europe could grow resource productivity through circular economy practices by up to 3 percent annually, which would generate a primary-resource benefit of as much as €0.6 trillion per year by 2030.[3]

[3] https://www.ids.ac.uk/opinions/what-is-the-link-between-productivity-circular-economy-and-the-sdgs/

Section 2: Architecture of the Bioeconomy in Ireland

OVERVIEW

The following section describes the bioeconomy in Ireland in terms the following three major sub-components:

1. Agriculture, Forestry and Marine
2. Bio-based Materials and Chemicals
3. Bioenergy and Biofuels

The description of each of these sub-components is based on a template devised by Frank Geels and Bruno Turnheim of the University of Manchester which systematically describes each sub-component under the following headings: Overview; Major Actors; Policy Context; and Innovations for Sustainability.

2.1. Agri-food, Forestry and Marine

This section provides a description of Ireland's agri-food, marine and forestry sectors. These sectors form a major part of the bioeconomy as they draw on Ireland's natural resources and produce many of the biomass resources upon which Ireland's wider bioeconomy will be based.

OVERVIEW

The agri-food, forestry and marine system is inherently complex because it comprises a large variety of heterogeneous products, production processes and supply-chains. It encompasses everything from primary agriculture to food and beverage production, from fisheries and fish processing to forestry and forestry outputs. The agri-food system is typically characterised by long, often global, supply-chains with numerous actors. The construction of the value chain and the business model that supports the value chain varies considerably between sub-areas.

Primary (agricultural) production takes place on farms, which in Ireland are dominated by relatively small family-farms, producing a variety of different crops, milk and meat.

Agricultural products are processed and packaged within the processing or manufacturing sub-system. Food processors are important actors in many chains (e.g. butchers and meat dealers in food chain, milk processors in the dairy chain, and mills for processing feed). The food processing sector in Ireland is made up mainly of SMEs which primarily serve the domestic market.

Distribution and retail subsystems link production and consumption. Over recent decades, the intensification, specialisation and globalisation of agri-food have tended to concentrate

significant power in large corporations in the distribution and retail sectors. Supermarket chains dominate food retail activities in Ireland and exert considerable influence on the configuration of agri-food systems up- and down-stream.

Food consumption is an inherently cultural practice, traditionally associated with positive meanings including quality of life, sociability, and pleasure. Consumer engagement is high with consumers engaging daily with food shopping, cooking and eating practices. However, there is also a relatively low degree of consumer knowledge about food production and supply, partly because supply-chains have become increasingly complex and international.

POLICY DRIVERS INTERNATIONALLY

The globalisation of food chains has led to significant national specialisation for export (e.g. beef and dairy in Ireland) along with increased reliance on imported foods (e.g. cereals, fruit & vegetables in Ireland). There has also been a long-term trend towards maximising yields and production quality in agriculture and farming which has contributed to increased food availability, but also created concerns regarding sustainability.

These sustainability concerns are increasingly steering agriculture internationally. Agriculture is required to play a role in mitigating GHG emissions, including the use of forests, soils and oceans as major carbon sequestration opportunities by acting as reservoirs. Agriculture is also increasingly adopting circular economy principles by supporting restorative and regenerative practices, and resource-efficient production and distribution systems to maintain and enhance natural capital. And finally, agri-food systems globally are moving into the wider bioeconomy by developing value-chains based on new and more efficient use of wastes, residues and by-products.

OVERVIEW OF LOW-CARBON PERFORMANCE IN IRELAND.

In Ireland, agriculture accounts for around 33% of national greenhouse gas emissions. This figure reflects both the significance of agriculture in the Irish economy and Ireland's lack of heavy industry. The highest climate impacts are associated with meat and dairy products. Methane (CH4) and nitrous oxide (N2O) make up the majority of Irish agriculture greenhouse gas emissions, mainly due to the dominance of cattle in Irish agri-food production. Emissions from agriculture in Ireland reached a peak in 1998. Data for 2015 indicate that agriculture emissions are 5.5% below 1990 figures, reflecting a long-term decline in livestock populations and in fertiliser use, due to policies and measures implemented under the CAP. The most recent projections, which take into account increases in production outlined in *Food Wise 2025*, forecast agricultural emissions to be just below the 2005 level and will put considerable pressure on the sector, despite the significant improvements to emissions intensity that have been achieved.

MAJOR ACTORS

The Irish agri-food industry is the main indigenous industry in Ireland, using Irish raw materials, being predominantly in Irish ownership, and spread geographically widely across the country. At primary production level, some 140,000 farm families are involved in production of output valued at more than €7 billion. Together the beef and dairy sectors account for almost 70% of this output value.

The Department of Agriculture Food and Marine and its agencies play an important role in Ireland's agri-food, marine and forestry system. Its roles include regulator (nitrates; animal production, health and welfare; feeding stuffs; crops and horticulture/plant health), development, promotion and support (CAP, direct payments, market support, state aids, access to finance, agri-taxation and social protection, and research and innovation). DAFM's agencies include Teagasc, Bord Bia, BIM, Coillte, Marine Institute, and the Sea Fisheries Protection Agency. Through its role in regulating, supporting and promoting the agri-food sector, DAFM plays a role in the construction of the value chain and the business model of agri-food supply chains.

In the private sector, IBEC, Ireland's largest business representative body, is active via Food Drink Ireland and through a number of fora including the Prepared Consumer Foods (PCF) Council, Dairy Industry Ireland, the Regulatory & Environment Committee, and Skills Hub.

The Dairy Sector

The dairy industry is central to the Irish agri-food sector. It is an export driven sector with exports of dairy products and ingredients valued at over €3bn in 2014. The abolition of the EU Milk Quota regime has presented the sector with the opportunity for significant expansion.

While historically Ireland's dairy product mix was weighted towards commodity output, an increased emphasis is now being placed on adding value, for example with infant formula production and ingredients, higher value premium cheeses and butters, as well as nutrition products and ingredients. Continued innovation in areas such as food formulation and structures, sports or functional food bioactives, nutrition, food with health/medical claims such as health and wellness through the life course (e.g. healthy aging) present further potential opportunities for higher value products. The role of food in influencing gut health (microbiome) and healthy microbiota and development of foods and food processing innovations to promote gut functioning also present further potential opportunities for higher value products.

Key elements of the dairy sector include Dairy Industry Ireland which provides a forum for industry to address complex environmental legislation at factory level as well as the National Dairy Sustainability Initiative to address the sustainability challenges facing the industry. Key actors in research & innovation for diary include Enterprise Ireland's Dairy Processing Technology Centre, MilkVista (co-funded by SFI and DAFM), Enterprise Ireland's Food for Health Ireland Technology Centre, and the SFI Alimentary Pharmabiotic Centre (APC).

The Meat Sector

Beef accounts for 34% of the gross output of the agriculture sector. 90% of Irish beef is exported, making Ireland the biggest net exporter of beef in the EU and the 5th biggest in the world. Over 100,000 farms contribute to beef production in Ireland. The strong reputation of Irish grass-fed beef production provides the basis for increasing exports of Irish beef to new global markets. The expansion of the dairy herd in response to the lifting of the EU Milk Quota will have a knock-on effect on the beef sector with the potential to correspondingly increase beef output.

The Irish pig-meat industry accounted for almost 8% of the output value of the agri-food sector in 2014 and is the third most important sector after dairy and beef. There are approximately 440 commercial pig producers in Ireland. Primary output from the sheep industry is currently worth about €230 million. Over two thirds of output is exported, with domestic consumption accounting for around 30% of overall production.

Key actors in research & innovation for meat include Enterprise Ireland's Meat Technology Ireland centre.

Prepared Consumer Foods

The Prepared Consumer Foods (PCF) sector comprises companies producing value-added food and beverages and includes prepared consumer foods, ingredients, value-added seafood, value-added horticulture and non-alcoholic beverages. The PCF sector has a gross output of €4billion. There are approximately 500 manufacturing units in Ireland, 76% of which are small companies.

Unlike the beef and dairy industries which are broadly export orientated, the PCF sector is heavily reliant on the domestic market. Innovation in this sector could potentially drive import substitution and increase the sector's 40% share of the domestic market. Key actors in research & innovation in this area include the DAFM funded Prepared Consumer Food Centre.

Sea Food & Aquaculture Sector

The Irish seafood sector currently represents around 5% of total food and beverage exports. Export markets for seafood are growing rapidly, with China now the world's largest importer of seafood. Ireland has a natural advantage in this sector, being adjacent to some of the most productive fishing grounds managed under the EU Common Fisheries Policy (CFP). The growth opportunity in the seafood sector lies in developing greater processing scale so as to capitalise on the expanded supply of raw material and from the landing into Ireland of quota compliant catch from other countries fishing in the waters around Ireland. Ireland's marine resource also provides Ireland with a major potential advantage in the marine bioeconomy.

The European Maritime and Fisheries Fund (EMFF) 2014-2020, managed by DAFM and administered by BIM, aims at increasing the competitiveness of the fisheries and aquaculture sectors through innovation and skills, while promoting a more efficient and sustainable use of resources. The Marine Institute plays a regulatory function in this sector as well as undertaking marine research and development.

Tillage Sector
Tillage crop production is based on the provision of feedstuffs to the livestock sector and critical raw material to industries such as malting, milling, sugar, breakfast cereal and distilling. 75% of the annual national cereals harvest is used to produce animal feedstuffs, with the remainder of the harvest going to feeding on-farm, production of seed, export, or use in the food and industrial sector. New sources of protein is an area of focus internationally due to increased global population and the need to reduce the greenhouse gas emissions associated with meat production. Further growth opportunities include the use of oilseed rape oil, and the potential for growth in the sugar beet industry in response to the likely development of the sugar and ethanol markets internationally.

Brewing & Distilling
The alcoholic beverage industry in Ireland accounts for 75% of total beverage exports and is broken down into different sectors; spirits (which includes Irish Whiskey, Irish Cream and Irish Poteen/Poitín), Beer, and Cider manufacture. Ireland exports drinks to over 125 markets worldwide. Emerging markets in Asia and the growth of the craft alcohol market in the United States provide Irish companies with further potential to expand. The alcoholic beverage industry needs a strong sustainable base of dairy farmers and grain growers to supply inputs to both the brewing and distilling sectors.

Horticulture
The horticulture sector contributed over €400m to agricultural output in 2014. The domestic market is generally the most important market, although mushrooms destined for the UK market represent a major export with a value in excess of €115 million. Innovations in integrated management of production, bio-actives, circular practices, technology and advances in plant genetic research and plant phenotypes present the sector with the potential to grow its output value to over €500m in the medium term.

Forestry
Forests currently make an estimated €2.3 billion contribution to the Irish economy and play an increasingly important role in rural development. Forests account for almost 11% of Ireland's land area and support a vibrant, export-oriented forest products sector, with over 75% of the output of Ireland's timber processing sector and 80% of wood-based panels being exported. Ireland, with growth rates of certain species well in excess of those achievable in some European countries, also has a strong comparative advantage in the growing of wood fibre. Ireland's forest cover, however, is well below the European average, which presents opportunities for further afforestation.

After wind energy, wood fuels are the largest contributor to renewable energy generation in Ireland. Forests' contribution to climate change mitigation through carbon sequestration and the use of wood products form an important element of the national climate change strategy. Afforestation supports Ireland's approach to land-based climate change mitigation and helps to reduce dependence on fossil fuels.

POLICY CONTEXT

Policy context in Ireland

The Irish agri-food sector is currently on a very significant growth trajectory. Ireland's agri-food strategy *Food Wise 2025* aims to increase the value of primary production in Ireland by 65% to almost €10 billion and increase the value of agri-food exports by 85% to €19 billion per annum by 2025.

The strategy identifies significant growth opportunities across all subsectors of the Irish agri-food industry. Export growth will be driven chiefly by expansion in dairy, beef, seafood, consumer food, and drinks exports. Within these sub-sectors the role of value-added products will be central. Innovation will be needed to increase sustainability and the proportion of value-added products which target different life-stage requirements, respond to increased demand for convenience and well-being, and provide products with clear nutritional and health benefits. Access to new markets, particularly China and other developing markets, is a second pillar of the strategy.

At the same time, however, Ireland faces significant challenges in meeting national and international environmental targets for air quality, biodiversity and water quality. *Food Wise 2025* recognises that the planned increase in food production cannot be considered in isolation from its environmental impact and that future food production must focus on managing and sustaining natural resources. Meeting greenhouse gas (GHG) and ammonia emission reduction targets will be particularly challenging, but arresting biodiversity losses and continuing the improvement of water quality while increasing production will be equally demanding.

Patterns of food consumption are deeply embedded in cultural practices and conventions. An increasing focus on convenience means that food consumption habits have changed to incorporate a greater amount of processed or convenience foods (through e.g. ready-meals, labour-saving preparation), as well as fatty and sugary foods and drinks, leading to concerns regarding the increased likelihood of health problems such as obesity and diabetes. Consumption of animal-based protein and potential for plant-based protein aimed at reducing the carbon footprint is also now in focus e.g. flexitarianism.

INNOVATIONS FOR SUSTAINABILITY

Main low-carbon innovations

Policymakers in Ireland have traditionally played a strong strategic role in agricultural planning oriented towards achieving an industry focus on sustainability, markets, competitiveness, food security and productivity increases. Policy in recent years has focused increasingly on technological innovation as a means for achieving policy goals, including an increased focus on sustainability.

Teagasc[4] identifies the main low carbon innovations in agriculture under three headings: (i) Agricultural mitigation measures which cover a range of innovations including accelerated gains in the genetic merit of dairy cows, and improved beef genetics (maternal traits and live-weight gain), as well as a move to more GHG-efficient fertilisers; (ii) Land-use mitigation strategies to enhance carbon (C) sinks or reduce C loss from agricultural soils, which would principally be achieved through increased afforestation, reducing losses on organic soils and enhancing pasture sequestration; and (iii) Energy measures include the use of biomass (woodchip and perennial biomass), energy saving on farms, and the adoption of grass fed AD to provide biomethane for the national grid and transport.

Additional innovations include maximising the contribution of agri- materials and residues to decarbonisation and materials displacement; and addressing methane and nitrous emissions through the use of best available science to reduce the impact of these gases on climate change.

Internationally, a biotechnology revolution in food production is taking place aimed at critical areas such as animal and plant breeding, feed efficiency, disease resistance and mirobila strain development. One example of the application of biotechnology for sustainability in Ireland is the Department of Agriculture, Food and the Marine's Beef Data and Genomics Programme (BDGP). The €300 million programme is addressing weaknesses in the maternal genetics of the Irish suckler herd and aims to reduce the greenhouse gas intensity of Ireland's beef production. Genomics is also being widely applied within the dairy industry in Ireland.

Innovation in food processing and manufacturing will also be important. Innovations in food technology, alongside demands for increased sustainability, are making the development of new food and drink products possible. In general, the food industry is a fast-paced industry with a significant degree of innovation (e.g. high number of new product launches), but these are mostly low-tech process innovations (e.g. relatively low investment in R&D, collaborative and incremental innovation). The challenge for food processors in Ireland, many of which are SMEs, is to engage in more radical innovation that will produce products for global markets. A key question is whether food processors in Ireland will be willing and able to develop into producers of biobased material intermediaries.

TRANSITION TOWARDS SUSTAINABILITY

The agri-food system is a distributed system, both in terms of network chains (inputs, primary production, processing, retail, consumption, waste) and technologies/innovations (i.e. there is not one dominant technology that can be replaced, but there are many innovations that together make up the system). This means that the transitions within the agri-food system to sustainability are likely to follow a gradual reconfiguration pattern where many innovations need to be aligned, rather than a rapid disruptive pattern. Internationally, there is growing

[4] An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030, Teagasc, 2018

scientific consensus that alongside biotechnology-based innovations, there will be the need for dietary shifts, increased attention to issues of waste reduction throughout food chains, and more ambitious agro-ecological transformations. Dietary shifts, which may be the one option with the largest potential, is also one of the most difficult options for which to envisage legitimate and effective interventions, due to its inherent link to individual behaviours and preferences.

A key point in the transition, however, is how to get the low carbon practices necessary to lower GHG emissions carried out on all farms, in terms both of who is responsible, and what partnerships are required to carry this out. Fines related to GHG emissions will remain a key influence in driving the transition.

SUMMARY OF ENTERPRISE OPPORTUNITIES

Ireland has an established enterprise base in agri-food, forestry and marine. Enterprise Ireland has an active client base and future opportunities have been identified in *Innovation 2020* and *Foodwise 2025*. These opportunities include firms providing processes and technologies which improve productivity and sustainability of production and food safety, and value-added products including food for health, nutraceuticals and functional foods and personalised nutrition.

Existing companies can be categories broadly as firms who are innovating in order to comply with regulation and standards with respect to sustainability; a smaller cohort of firms who are providing technology and services solutions; and lead innovators who are developing or adopting leading edge technologies and services solutions.

The primary importance of this sub-system to the bioeconomy is as producer of the biomass that will underpin the other components of the bioeconomy.

The challenges for the agri-food, forestry and marine sectors in this regard lie in the need for existing actors to recognise biomass as an additional potential revenue stream, and for primary producers to become part of bioeconomy value chains. This will include significant changes at the level of individual farmers.

2.2 Bio-based Materials and Chemicals

OVERVIEW

Renewable biomass is envisaged to become a major source of inputs for the production of chemicals, plastics, textiles, materials and fuels in the future. This new component of the bioeconomy will depend on the sustainable production and harvesting of biological resources and residual waste flows across multiple sectors, including agriculture, marine, forestry and the waste sector.

The systems linking biomass inputs from production to consumption are still in the early stages of development. Significant innovation and technology development will be required in fostering sustainable biomass supply, building new supply chains, optimising efficient processing and piloting, and demonstrating the efficiency and economic viability of large-scale demonstration biorefineries. It will also require the development of markets for bio-based products.

Such systems will be complex due to the variety of biomass inputs and the wide range of bio-based products involved. The balance between local value chains, where biomass is sourced and processed locally, and global value chains, where biomass production and consumption is internationally distributed, is yet to be determined. What is clear is that biorefineries will perform the crucial processing step between biomass production and bio-based product manufacture and will therefore play a critical role within the development of this component of the bioeconomy.

Ireland is well placed to develop opportunities for bio-based chemicals and materials production due to an abundant natural resource base, productive soils, ocean resources, high biomass growth rates, and a need to manage residual waste flows. Much of the terrestrial advantage in Ireland stems from the significantly long growing season resulting from the temperate climate and fertile soils, with potential for growth up to 10 months of the year. Ireland's long growing season and rainfall patterns generate one of the highest biomass growth rates of any country globally.

As outlined above, agri-food is the largest indigenous business and accounts for 5.7% of our GDP. In addition, approximately 10.7% of Ireland is under forests which produce 3.2 million cubic metres of material each year and this is forecasted to increase to 8 million by 2035. Ireland has one of the largest seabed territories in Europe which is about 10 times its landmass and is an enormous reservoir of genetic material with a vast natural product potential. It is clear, therefore, that Ireland possesses key advantages in terms of potential for biomass production.

However, demand for biomass in a fully developed bioeconomy is likely to far exceed supply unless the overall bioeconomy system is managed according to circular economy principles so as to restore and regenerate natural resources. Due to sustainability concerns, utilising waste streams as a significant input to biorefining processing is an early consideration for the development of a sustainable bioeconomy. The Irish agricultural and food sector generates a number of organic wastes that require management, are currently underutilised, and could underpin the early development of the Irish bioeconomy. There is also significant potential to examine the bio-refinement of wastewater and municipal solid waste.

One challenge in the development of the bioeconomy will be the attitude of consumers towards new biomass-based products and regulation to allow waste streams to be utilised. As outputs of biorefineries are typically intermediate products that form inputs to the manufacture of a range

of goods, the uptake of these intermediaries by manufacturers will depend in part on consumer attitudes to biobased products.

MAJOR ACTORS AND VALUE CHAINS

Biorefineries

Industrial biorefineries have been identified as the most promising route to the creation of new biobased industries. A biorefinery can be defined as a processing plant where biomass feedstocks are converted into a spectrum of valuable products.

Feedstocks for biorefining can be grouped as follows:

- Energy crops from agriculture (e.g. starch crops, short rotation forestry) currently constitute the major feedstocks for existing biorefineries worldwide
- Biomass residues from agriculture, forestry, marine trade and industry (e.g. lignocellulose such as straw, bark, oils & fats, waste streams from biomass processing)
- Feedstocks from the waste sector (wastewater, municipal solid waste)
- Protein from novel sources (aquatic organisms, insects)

Together these feedstocks appear to be the most promising sources for the new bioeconomy.

Biorefinery models have evolved from ethanol mills using food crops as feedstocks to more complex models using a variety of other feedstocks. The ultimate goal is the development of an integrated biorefinery that can use multiple feedstocks and generate multiple products (fuels, chemicals, materials, electricity). However, biorefineries are still currently in the early stages of development, are capital intensive, and are seen as high-risk investments. Marine biorefineries are proving to be particularly technologically challenging but very significant EU investment is aiding development in this area. Ireland, through BioMarine ingredients, already has in place the first pilot marine biorefinery in the EU.

Small-scale biorefineries, while at an early stage of development, hold enormous potential for the bioeconomy, particularly for rural and coastal regeneration. Small-scale biorefining plants would significantly reduce capital investment requirements, a key barrier to uptake of bio-based technologies. These technologies, if developed, would represent a potential model through which farmers and foresters could become more central stakeholders in the bioeconomy, rather than simply biomass suppliers.

Agriculture

As described in detail in Section 1, the agriculture sector constitutes an important source of biomass for the future bioeconomy. Of the wide range of Ireland's potential biomass resources, Teagasc's recent BioEire study identified three agri-food value chains of particular potential. The first of these is already being exploited.

Processing of Diary Side Streams to High Value Bio-based Chemicals

Ireland has a well-established dairy sector and this value chain represents a natural progression from existing dairy industry successes. The European dairy industry, as a by-product of whey protein manufacture, produces substances known as whey permeate and, following extraction of lactose, delactosed whey permeate. The AgriChemWhey project in Lisheen is the world's first integrated biorefinery for converting food-processing residues to bio-based chemicals. It aims to convert these waste sidestreams into added-value products, specifically L-Lactic acid, polylactic acid, minerals for human nutrition and bio-based fertiliser, for growing global markets. The AgriChemWhey project is a consortium of Irish and European institutions, including Glanbia Ingredients.

Processing Horticultural By-Products to Biopolymers

The potential for this value chain stems from possible utilisation of waste material from the horticultural industry, based on the ease at which such lignocellulosic material can be processed to create higher value outputs. Monaghan Mushrooms is a partner in the EU funded project FungusChain which aims to take agricultural offcuts of commercial mushroom farming and process these offcuts into bio-based functional additives and biopolymers and further into a spectrum of products (food supplements, cleaning products, commercial plasticizers and industrial films). A perceived strong consumer demand and market for more sustainable packaging increases the potential of this value chain opportunity.

Processing Sugar-Yielding Feedstock (Grass) to Biochemicals

Other potential options include biomass from semi-natural habitats as inputs for biorefining. This includes grass, where potential material, chemical and energy uses exist for both grass fibres (e.g. silica and cellulose) and grass juices (e.g. sugar proteins, colourants, alkaloids and insulin). The potential of this value chain is enhanced by the natural advantage in grass growth in Ireland and the appeal associated with using second generation feedstocks, as opposed to first generation feedstocks which would compete with food for land and other resources. The output from this value chain could also potentially include biofuels and bioenergy. The Carbery Group are partners in a European Innovation Partnerships Initiative on small scale farmer-led green biorefineries in this area.

Marine

Ireland's marine resources represent a significant potential advantage in the new bioeconomy. Two value chains identified in the BioEire study use marine biomass as a source.

Processing of Marine Discard to Functional Foods

The potential of this value chain rests on the already well-established marine food industry in Ireland and readily-available input supply and the strong (and growing) market demand for alternate proteins and functional food outputs. This value chain could also potentially contribute to economic regeneration of coastal communities. Biomarine Ingredients have built Europe's first marine pilot biorefinery in the EU, at Lough Egish, County Monaghan, from private resources. Due to the technical challenges, continued investment in research as well as the

development of international collaborations are necessary to realise the potential of this value chain.

Processing Seaweed to High Value Products
The potential of this value chain revolves around a perceived abundant supply base, already established research and SME activity, and the nutrient- and bioactive-rich properties of seaweed. Valuable bioactive molecules in seaweed are known and extraction technology methods have been established. There is also potential for seaweed processing to provide biochemicals for animal feed to reduce GHG emissions. Challenges associated with this value chain relate to scale, regulatory issues with the industrial harvesting of plants, and turbary rights for small scale seaweed harvesters. Irish companies active in this area include NutraMara and BioAtlantis. Over 100 projects have been funded through the EU R&I BBI programme, suggesting that there is significant potential in this area.

Industries Involved in Final Production

If biorefineries are the key link between biomass production and the producers of biomass products, then industries which use the outputs of biorefineries as inputs for their production processes are the next vital part of the value chain. In Ireland, this range of potential industries beyond food and feed includes wood-based materials; pulp & paper; platform and fine chemicals; fibres; pharmaceuticals; composites; lubricants; polymers; energy and fuels.

Pharmaceuticals stands out as being of particular potential significance as 24 of the 25 largest bio-pharmaceutical companies have a presence in Ireland, with the sector producing €39bn in exports. The potential for increased alignment of the biopharma sector with current and future bioeconomy actors is a key area to be explored. However, it should be noted that companies currently active in the production of biochemicals and biomaterials typically look to global markets for their outputs, rather than targeting Ireland's existing industrial base.

POLICY CONTEXT

International context

The use of biomass for the production of chemicals and materials has generated significant international debate. At the international level, it is expected that many OECD countries, because they are relatively biomass poor, will become net biomass importers. Many developing and poorer nations, on the other hand, are biomass rich and are expected to become exporters of biomass. In the absence of strong international governance, biomass could be over-exploited as a resource, potentially resulting in food shortages and price hikes, deforestation and soil destruction in developing countries. Simply relying on the export of biomass resources may also inhibit technological development for developing countries. Such concerns over the negative consequences of global biomass flows highlight the importance of developing the global bioeconomy in a sustainable manner and for national policies to be designed within the context of the global bioeconomy.

The cascading principle, which has been developed at EU level, and adopted in *Ireland's National Statement on the Bioeconomy*, seeks to balance the competing demands for biomass at both national and international level. According to the cascading principle higher value applications are preferentially derived from biological resources (e.g. food, bio-based materials and chemicals) prior to their use in energy and fuel generation, in order to allow the maximum value to be derived from bio-resources.

INNOVATIONS FOR SUSTAINABILITY

The development of the chemicals and materials subsystem of the bioeconomy will require innovation across biomass production through biorefining to the usage of bio-based intermediaries by industries engaged in chemical and materials production.

On the biomass production side, the range of value chains identified above point to agriculture and waste streams as among the most promising biomass sources in Ireland. The crucial linchpin will be the development of biorefining technologies for processing of this biomass. A range of technologies are currently being pursued globally using a diverse range of biomass sources. As outlined above, a number of biorefinery projects are currently underway in Ireland.

In all countries, the chemicals and materials sub-system of the bioeconomy is currently still under construction and the crucial central technology (biorefineries) is still at developmental stage. The development of the new bioeconomy in Ireland is therefore likely to initially follow a gradual development pattern where many innovations – in technology, value chains, regulation and governance - will need to be aligned.

SUMMARY OF ENTERPRISE OPPORTUNITIES

The biomaterials and biochemicals component of the bioeconomy in Ireland is still very much in a nascent stage. The small number of companies active in this area are generally lead innovators who are innovating in multiple areas including developing technology, establishing value chains, and sourcing global markets.

In Ireland, innovation policy to date has been designed to target investments in science and technology in order to maximise the economic impacts of those investments. Policy instruments currently in place include support for basic research in universities and tax credits and direct subsidies for R&D in firms, and a range of policy instruments aimed at strengthening the overall innovation system. These include cluster policies to stimulate collaboration between firms, research centres to increase links between firms and higher education institutions, education policies to support the absorptive capacities of firms, policies which focus on entrepreneurship, support for high growth innovative firms, and policies to support the commercialisation of research carried out in higher education institutions. The SFI Beacon Bioeconomy Research Centre is an important initiative in this regard.

These policy instruments are all relevant to supporting lead innovators in the biomaterials and biochemicals part of the bioeconomy in Ireland. However, recent work by the OECD shows that

policies aimed at making the transition to more sustainable industries requires additional policy tools. The development and implementation of the *National Policy Statement on the Bioeconomy* is based on this 'system transition' approach to policy recommended by the OECD. The instigation of a Disruptive Technologies Innovation Fund, designed to support large scale demonstrations of disruptive technologies to address societal challenges, represents another important policy tool for potential use in supporting lead innovators in the bioeconomy.

Experience to date suggests that the sectors most likely to participate in biomaterials and biochemicals part of the bioeconomy will be the food, biotechnology/pharmachem, and energy industries. The Bioeconomy Implementation Group aims to engage these industries in forward planning for the development of this component of Ireland's bioeconomy.

2.3 Bioenergy and Biofuels

OVERVIEW

Biomass is likely to become a significant fuel source for the future low carbon economy, at least in the short term. Biomass can be used to produce electricity or thermal energy (bioenergy), or transportation fuels (biofuels). There will, however need to be trade-offs to ensure importing of biomass does not hinder sustainability globally and to manage the demand for biomass for food, high value chemicals and bioenergy.

Bioenergy

The energy stored in biomass can be released to produce renewable electricity or heat. Co-firing of biomass and fossil fuels (usually coal) is a low-cost means of reducing greenhouse gas emissions in existing power plants. Thermal energy (heating and cooling) often occurs at the scale of the individual building, through direct combustion of wood pellets, wood chips, and other sources of dry biomass.

Biofuels

A number of transportation fuels can be produced from biomass, helping to alleviate demand for petroleum products and improve the greenhouse gas emissions profile of the transportation sector. Ethanol from corn and sugarcane, and biodiesel from soy, rapeseed, and oil palm dominate the current market for biofuels. Biofuels as an option is important to consider in haulage transport, public transport, sea transport and aviation. While electrification may be able to play a significant role in decarbonising transport for private road transport (e-cars), for example, in these other sectors biofuels may be necessary in the absence of other solutions.

The sectors relevant to bioenergy and biofuels include the primary agriculture, forestry, catering, electricity, gas and oil sectors.

BIOFUELS

Biofuels are already playing an important role in the transport sector as a means of reducing GHG emissions. The Biofuel Obligation Scheme in Ireland places an obligation on suppliers to

ensure that 8.7% by volume of the motor fuel, generally gasoline and motor diesel, placed on the market in Ireland is produced from renewable sources. The obligation will increase to 10% by 2020. This provides an incentive for suppliers to use biofuels as part of the fuel mixture. The biomass for biofuels currently comes mainly from energy crops, agricultural and food waste (including cooking oil), and technologies that convert industrial gases to biofuels. The majority of biofuel in Ireland (85%) is imported.

There are limitations in biofuel blending, however, as many older cars cannot use fuel mixtures with too high a concentration of biofuels. The main focus of policy in Ireland and internationally with respect to cars is to incentivise private motorists to buy electric cars. Biofuels are being viewed as an option for other forms of transport, particularly freight.

Energy Crops

70% of Irish agricultural output is in the beef and dairy sectors and the majority of Irish grassland is currently used for livestock production. There is, however, potential for energy crop production for biofuel production. *Food Wise 2025* suggests that improved utilisation of grassland could support increased livestock production while making substantial areas of pasture land available for conversion to arable land. Some of this converted pasture land could be used for growing energy crops.

Conventional arable crops can be used as feedstocks for biofuels. Starch crops such as wheat can be fermented to produce bioethanol (a substitute for petrol), and oil from oil seed rape (OSR) can be converted to biodiesel. Both wheat and OSR are currently grown in Ireland but are used either for food and fodder or for export; neither is currently used for biofuels production domestically. Energy crops currently yield lower profits than beef and dairy production.

This area highlights the potential competition for biomass within the bioeconomy. Energy crops presents a potential risk to grass supply for fodder. They also present a potential risk for indirect land use change and to biodiversity. There is also the potential for grass crops to be first biorefined for proteins and other high value content prior to producing energy. Such concerns over increased production of energy crops therefore makes the potential utilisation of waste streams an attractive option.

Cooking Oil for Biodiesel

Used cooking oil (UCO) can be collected, filtered and used as a feedstock in the production of biodiesel. The main sources of UCO are catering premises, food factories and households. Commercial services currently collect UCO from catering premises and food factories, and some companies supplying oil to catering companies offer an integrated service that includes the free collection of used oil. There is currently no collection of UCO from households in Ireland. A number of companies in Ireland operate biodiesel plants which uses a variety of feedstocks including UCO, tallow and plant oils to produce biodiesel or other renewable transport fuels. These include Green Biofuels Ireland in Co. Wexford and Irish Biofuels Production Limited in Co. Wicklow.

Municipal Solid Waste to Biofuel

While the technological and commercial feasibility of the conversion of Municipal Solid Waste (MSW) to biofuels is still under development, the world's earliest (MSW) biorefineries are now in operation. Two high-profile biorefineries have been established in the U.S. and Canada through public-private partnerships to convert MSW into bioethanol and methanol. The facility in Ineos Vero Beach, Florida, which began operation in 2013, is currently producing 8 million gallons of cellulosic ethanol per year from vegetative and yard waste, as well as MSW. The other MSW plant is the Enerkem plant in Edmonton, Canada. Both are gasification and fermentation plants i.e. gasification is needed to get MSW ready for use as a feedstock for biofuel production.

Industrial Gases

Gas fermentation technology that exploits the potential of waste CO2 and other industrial gases to produce biofuels is now being actively pursued, although the technologies are still in their infancy. The top three industrial GHG emitters are steel, cement and chemicals. Biorefining technology based on industrial gases would help these industries reduce emissions, while adding value to their core business. This technique does not compete for land or interfere with food as no crops are required. Industrial sources of CO2 are already used for specific purposes, such as for carbonating soft drinks. The feasibility of converting industrial gases to bioethanol has been demonstrated at laboratory scale. LanzaTech, a waste gas-to-fuel and -chemicals start-up founded in New Zealand, converted steel mill waste gases to ethanol at demonstrator level in 2013. A system to be built at an ArcelorMittal steel mill in Ghent, Belgium would be about 30 times larger than the LanzaTech plant. If the system proves to be commercially viable, ArcelorMittal, the world's largest steel maker, hopes to install it across its operations. This technology could potentially produce up to 10% of Europe's bioethanol a year.

BIOENERGY

Teagasc's BioEire study identified agri-food waste streams as the source of biomass in the following potential bioenergy value chains:

Processing of Agricultural Waste to Biogas

The potential of this value chain is supported by an abundant supply base, proven and continuously improving technology options, high demand for renewable gas, minimal biomethane conversion costs and the production of a nutrient-rich digestate for land spreading post- processing. Perceived environmental benefits of this value chain include its ability to act as a waste management solution for farmers, while also reducing the GHG emissions and environmental impact associated with agriculture. Additional potential economic advantages include diversifying farm income and assisting rural development.

Processing Food Waste to Biogas

The positives associated with this value chain include adding value to a waste resource, capitalising on a waste collection system that already segregates waste, and existing high market demand for biogas. Other advantages include the lack of conversion costs to consumers to switch to biomethane, along with key drivers associated with new food waste collection

legislation and landfill bans. There are existing examples of proven technologies and international best practice in this area which Ireland could adopt. In line with circular economy principles, food waste first needs to be minimised to ensure the overall sustainability of this value chain.

Forestry

The Irish forestry sector is dominated by the state sector. The state body Coillte manages most of the 11% of Irish land area that is currently forested, although private holdings are now increasing. The Department of Agriculture and Marine's 2014 report *Forests, Products and People: Ireland's Forest Policy – A Renewed Vision* outlines the government's plans to increase Ireland's total forested area to 18% of the country and make available 1.45 million cubic metres of wood to the bioenergy sector by 2020, increasing to 1.75 million cubic metres by 2028. Waste products from forestry (e.g. sawdust, woodchips) are valuable inputs into the bioenergy sector as they can be readily turned into solid fuel with little refining. Waste wood, from construction for instance, serves a similar purpose. There are potential air quality issues with this, however, and air to heat pumps may provide an alternative energy/decarbonisation option for private dwellings into the future.

The BioEire study identified the following forestry-based value chain as having potential for Ireland:

Processing Forestry Thinning to Heat Generation

Advantages of this value chain are the availability and underutilisation of current biomass supply, the fact that the necessary transformation technology exists, and the potential to reduce dependence on fossil fuels and mitigate climate change. Creating consumer demand is an essential step for success, with some concerns regarding the collection, supply volumes and distribution of forestry thinnings. Concerns also exist that the business incentive is not in place to invest in the necessary infrastructure for decentralised heat generation when gas is currently being used by mass users such as hospitals, universities and hotels at a higher fuel efficiency.

Power to Gas

Power-to-Gas (PtG), a technology currently under development, could play a significant role in the future energy system. The PtG process links the power grid with the gas grid by converting surplus electrical power into gas via a two-step process: hydrogen production by water electrolysis followed by hydrogen conversion to methane. The resulting methane, known as substitute natural gas (SNG), can be injected into the existing gas distribution grid or gas storages, or used as motor fuel. Direct injection of hydrogen into the gas grid is possible but is limited by regulation for safety reasons.

The main drawbacks of Power-to-Gas at present are its relatively low efficiency and high costs. There is a significant amount of Power-to-Gas research being carried out internationally including in Germany, France, Switzerland, Denmark and Japan, where pilot plants are under construction or in operation. The economic viability of Power to Gas increases as the cost of

electricity decreases with increased electricity generation from renewable sources including wind, solar and ocean energy.

Power to Gas is of interest in the freight sector as a source of compressed natural gas as a fuel for heavy goods vehicles. Heavy transport is a sector where there are few options for emissions reductions as electrification is not viable.

Biomass in Electricity Generation

Co-firing of biomass and fossil fuels (usually coal) is a low-cost means of reducing greenhouse gas emissions in existing power plants. Biomass is not envisaged as playing a major role in future electricity generation in Ireland, where wind, solar and, potentially, ocean energy are anticipated to be the dominant future technologies.

POLICY CONTEXT

International Context

Bioenergy and biofuels carry a significant danger of unsustainable, over-use of biomass due to the volumes required, and could lead to deforestation and food shortages due to land use for biomass production. The OECD raises concerns regarding the global transition to a bioeconomy, pointing out that the total supply of sustainable biomass in 2030 may be enough to fulfil the demand in a 10% bio-based economy and that a highly ambitious bioeconomy increases the risk of a non-sustainable supply and over-exploitation of natural resources.[5]

Arising from these concerns, and those linked to impacts on food prices, the EU Renewable Energy Directive establishes that biofuels must meet certain "sustainability criteria" in order for them to be counted towards national biofuels targets. Studies for Ireland show these "sustainability criteria" may affect the availability of bioenergy (especially biodiesel) for import, pointing to a potential need to produce greater levels of biomass locally. Promoting circularity and use of waste flows will both be necessary to reduce the tension between food and non-food uses of biomass, and to ensure sustainability.

Policy Context in Ireland

Bioenergy is seen as, potentially, an essential element in contributing to Ireland's future energy needs. SEAI's Bioenergy Roadmap presents one plausible scenario of over 3,500 kilotonnes of oil equivalent (ktoe) of indigenous resources being available for the bioenergy supply chain by 2050, delivering abatement of over 11 Mts of CO2 annually. The development of this bioenergy resource is also seen as central to overall energy policy in Ireland. It could assist Ireland in meeting its renewable energy targets to 2020 and beyond, making a contribution across the three sectors of electricity, heat and transport, and enhance security of supply through the displacement of imported fossil fuels. Developing the bioenergy sector can also help in achieving wider policy objectives in areas such as waste recovery.

[5] OECD Report: Circularity in the Global Bioeconomy, OECD, Paris

Two policy measures have been introduced in Ireland aimed at fostering the growth of bioenergy and biofuels. The Biofuels Obligation Scheme has resulted in a steady growth in biofuels in Ireland. In 2005, 0.03% of all transportation energy needs were met by biofuels, rising to 6.1% by 2017 and projected to reach 8% by 2020. The Support Scheme for Renewable Heat is designed to financially support the adoption of renewable heating systems by commercial, industrial, agricultural, district heating and other non-domestic heat users. It supports the installation of biomass heating systems or the conversion of existing fossil fuel heating systems to biomass heating systems.

INNOVATION FOR SUSTAINABILITY

Main innovations

The replacement of fossil fuels with bioenergy and biofuels rests on a diverse range of innovations. These include, for example, the usage of crops as biomass that does not require extensive inputs and can grow on marginal land that is unsuitable for other uses. This would simultaneously reduce emissions and reduce the burden that energy crops create for the food supply. Other innovations needed are the development of new sources of potential bioenergy, particularly in the area of waste. The SEAI has identified chicken litter, sewage sludge, fats, oil & greases, and macroalgae, for example, as areas where strong potential exists and where technological progress is expected. In some areas of bioenergy, however, the major innovations needed are in establishing supply chains, infrastructures and consumer demand, rather than technological innovation.

TRANSITION TO SUSTAINABILITY

Scenario analysis can be used to obtain insights into the possible future role of bioenergy in Ireland. The following analysis of three scenarios, each of which would provide a reduction of at least 80% in CO2 emissions below 1990 levels by 2050, has been carried out by the MaREI Centre, Environmental Research Institute, University College Cork.[6] This analysis shows that restrictions in bioenergy imports can have a major impact on the future role of bioenergy and biofuels in mitigating Ireland's GHG emissions.

Scenario 1: No limits on import of biomass. In this scenario emissions reductions by 2050 are achieved mainly by:

- a steep increase of biofuel consumption in the transport sector, delivered by bioethanol, biogas and biodiesel
- in the heating sector, biomass for heating becomes the dominant heating technology, supplemented by an increased use of biogas for heating

[6] The Role of Bioenergy in Ireland's Low Carbon Future – is it Sustainable?, Alessandro Chiodi, Paul Deane, Maurizio Gargiulo, and Brian Ó Gallachóir, Journal of Sustainable Development of Energy, Water and Environment Systems, Volume 3, Issue 2, pp 196-216, 2015

- electricity generation is dominated by wind generation, so no bioenergy is consumed in the electricity generation sector.

Scenario 2: Some limits on import of biomass due to the Sustainability Criteria (SC) of the EU Renewable Energy Directive. In this scenario emissions reductions by 2050 are achieved mainly by the following actions:

- in the transport sector there is a drop in biodiesel imports which is only partially balanced by higher domestic biogas production (potentially from grass) and increased imports of ethanol
- with respect to heating, electricity displaces biomass and biogas in heat
- renewable electricity grows to meet reductions in bioenergy consumption.

Scenario 3: A ban on import of biomass due to the Sustainability Criteria (SC) of the EU Renewable Energy Directive, so that mitigation targets may be achieved only by mean of Domestic Resources.

This scenario shows a similar pattern to Scenario 2, but with steeper reduction trends in bioenergy:

- The transport sector (freight and public transport) transitions from bioliquids to biogas, while about 40% of freight fleet consumes hydrogen (from gasification of coal with CCS).
- The heating sector moves further from bioenergy to electricity which shows increased levels of renewable generation from onshore and offshore wind, solar and some ocean energy. By 2050 electricity becomes the most important energy vector for meeting heat demand.

This analysis shows that with increasing constraints on imports, the future role of bioenergy and biofuels decreases, alongside an increased need for electrification of transport and heat – based on gas CCS and renewables (wind, solar and ocean), end-use efficiency, and hydrogen. Marginal CO2 abatement costs rise sharply in accordance with the level of import restrictions.

The coupling of bioenergy and biofuels with renewable energy for electricity generation, shown in these scenarios, highlights the importance of considering technology portfolios across energy, the bioeconomy and circular economy together, rather than considering individual technologies in isolation.

SUMMARY OF ENTERPRISE OPPORTUNITIES

At present, most of Ireland's current biofuels needs are met through imports, although a small number of indigenous companies are active in biofuel production. The membership of the Irish Bioenergy Association, with around 140 members ranging from state owned companies to SMEs, illustrates the current enterprise base in bioenergy in Ireland. The challenges for many companies in both bioenergy and biofuels include sourcing sustainable and reliable biomass and establishing value chains from biomass sourcing to market.

As the scenario analysis above illustrates, Ireland's biofuels and bioenergy sectors may need to grow significantly in the future, but such growth may be affected if restrictions on biomass imports come into effect.

Section 3: Architecture of the Circular Economy in Ireland

OVERVIEW

The following section describes the circular economy in Ireland in terms the following two major components:

1. The "Mechanical" Circular Economy
2. The Sharing Economy

The description of each of these components is once again based on a template devised by Frank Geels and Bruno Turnheim of the University of Manchester which systematically describes each sub-system under the following headings: Overview; Major Actors; Policy Context; and Innovations for Sustainability.

3.1. The "Mechanical" Circular Economy

OVERVIEW

There is increasing focus globally in moving away from a 'make-use-dispose' model of production and consumption towards adopting a circular economy model. According to the World Economic Forum, a fully circular economy requires a systemic and transformative approach to production and consumption that effectively designs out waste and keeps materials and products in use for as long as possible (World Economic Forum, 2015). In its Circular Economy Action Plan, the European Commission defines the "circular economy as the economic space where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (European Commission 2015). At present, most of the material flows globally – fossil, biomass, metals and minerals – are not part of the circular economy.

The circular economy is closely linked to the bioeconomy. Many bio-based materials are renewable, biodegradable and compostable and can become the basis for important circularity in an economy. The bio-based aspects of the circular economy encompass the Food, Feed and Marine, Biochemicals and Biomaterials, and Bioenergy and Biofuels subsystems of the bioeconomy outlined above. These biobased systems need to become not only carbon efficient but also circular.

This section, however, will concentrate largely on the mechanical (non-biological) aspects of the circular economy that haven't been dealt with in previous sections.

Current systems linking the value chain from design, production, distribution to consumption currently operate predominantly on a 'make-use-dispose' model. Changing this linear configuration to systems based on circular principles of waste reduction and reuse demands multi-level interventions across the value chain. The 'use, reuse' model at the heart of the circular economy requires a shift in how conventional product design, manufacturing and consumption is configured. At the design stage, the emphasis has to shift to product design (eco-design), where 80 per cent of a product's environmental impact is determined. Changes are also needed in manufacturing processes by making greater use of closed loop manufacturing whereby inputs are recovered and reused, and in greater use of sustainable materials to replace one-use-only inputs to production.

Distribution and retail subsystems will need to focus on reducing waste and creating value through the reuse of secondary materials, remanufacturing and repair services. With regard to waste, particular emphasis will need to be placed on reducing food waste, water management, and reuse of materials used in construction, which taken together account for a high proportion of materials use in society. Increased investments in infrastructures to enable increased circularity in these sectors will be required. This will require increased data flows & logistics systems connecting across diverse sectors.

Extending the product life of goods and reuse of materials requires a shift in consumer expectations. The social acceptability of recycled materials is high in some areas of manufacturing such as packaging and plastics. For many consumer goods, however, the attraction of recycled, repaired or remanufactured goods remains low.

MAJOR ACTORS

Manufacturing Processes

All major sectors of production in Ireland, including sectors such as Food and Drink, Pharmachemicals, and Medical Devices, are dependent on the sustainable supply of raw-materials. In these sectors it is particularly important to examine the feasibility of introducing circularity into production processes, including cooperation between companies across the supply chain to achieve a more effective circular patterns of resource use.

Circular manufacturing principles are already being applied in Ireland. Closed loop recycling, for example, aims to increase the value of recycled materials. Plastics are one of the materials that have received intense focus in recent decades with regards to closed loop recycling. The European Commission's Circular Economy Package identifies plastics as a priority material. Approximately 90% of the feedstock for the plastics industry is fossil based, mainly oil and gas. Wellman International, Europe's largest recycler of post-consumer PET bottles, is located in Co. Cavan. Wellman produces a range of fibres from plastic that are applied in a wide variety of products including home furnishings, automotive components, clothing and medical applications.

An example of recovery of components for reuse is waste electric and electronic equipment (WEEE). The WEEE waste stream in Europe is estimated to contain 300 tonnes of gold, 201,000 tonnes of silver and 16 million tonnes of steel. It also contains critical raw materials (CRMs), that are essential for the development of products in key sectors. Wisetek, based in Cork, is involved in the recovery of WEEE components for direct reuse and redistribution globally. Global WEEE regulation has played an important role in enabling such businesses to grow.

There is also potential for more sustainable manufacturing practices by developing new sustainable materials that are suitable for recycling and reuse. One significant area is 3D printing (additive manufacturing) which could have a dramatic impact on reducing the volume of materials used in manufacturing. Additive manufacturing could use 50 per cent less energy and save up to 90 per cent on materials costs compared to traditional manufacturing. The Enterprise Ireland funded Irish Manufacturing Research Centre is examining circular economy opportunities in this area.

Eco-Design

Product design is where 80 per cent of a product's environmental impact is determined. The 'use, reuse' model at the heart of the circular economy requires a paradigm shift in conventional product design towards eco-design which designs-in disassembly, reuse and recycling of the component materials. There has been slow progress globally in making the shift across supply chains, however. Barriers exist at the design stage of manufacturing as many products are currently designed and manufactured to minimise production costs and stimulate their fast replacement with newly manufactured products.

Mechanical Recycling and Reuse

Within the circular economy, reuse and repair are dominant strategies for extending the life of products, reducing material inputs and minimising waste. In some product categories, the commercial viability of reuse and repair has led to the development of established markets e.g. repair services are a well-established aspect of the automotive sector. In other product categories, such as white good and electronics products, the market and social practices for repair and reuse have weakened over recent decades.

A number of relatively low-cost interventions have been shown to work with traditional repair and leasing sectors. For example, as part of its Energy Transition for Green Growth Act, the French Government mandated that all auto repair providers need to offer customers repaired and remanufactured parts. The Swedish government is trialling a reduced VAT rate on repaired goods to incentivise the greater use of repair instead of purchasing new products. Public procurement can also play a role in providing a market for recycled and reusable products. In Ireland, the EPA has supported the development of reuse and repair through the Community Reuse Network (CRNI) which comprises 16 national community reuse organisations.

Solid Waste Management

Solid waste management is an important sub-sector of the circular economy. Disposing of solid non-biomass waste materials by landfilling or incinerating is still the dominant disposal pattern

worldwide, resulting in loss of valuable resources and heavy environmental impacts. Recycling of solid waste offers the opportunity to benefit from still usable resources and reduce the quantity of waste that need to be treated and or disposed of. In a 2016 European Commission survey that explored SME activities in relation to the circular economy, 73% of European SMEs indicated that they have invested in the transition to a more circular model for their businesses over the past three years. Of the actions taken by Irish SMEs, waste management was the most active area of investment.

The establishment of well-organized waste management services (collection, transportation, processing and disposal) along with citizens' awareness of, and high expectations towards, such services are an important factor underpinning the development of the Circular Economy for solid waste. While progress has been made in introducing solid waste management strategies in Ireland, the reliance on export of solid waste and energy recovery, and a lack of infrastructure such as a glass manufacturing facility, paper mill or metal smelter, presents a challenge with regards the circular economy here. The opening of Ireland's first municipal waste incinerator in 2012 has increased the recovery of municipal waste as a fuel.

Food Waste

Food waste – a category of biomass - is a key area in the circular economy. Internationally, it is estimated that between 30%–50% of food intended for human consumption is wasted at different stages of the food system. Increased pollution and greenhouse gases result from high levels of food waste. In developing countries, food losses and waste occur mainly in the production stage due to poor harvesting, poor storing conditions, and inefficient transportation and logistics. In developed countries, up to 40% of losses occur at the consumption stage i.e. at retailer and householder level.

Circular economy regarding the food system implies reducing the amount of waste generated in the food system, re-use of food, utilization of by-products and food waste, nutrient recycling, and changes in consumer food practices and diet. Within the food production system, the major area of focus is prevention of food surplus. Where food surplus does occur, the emphasis is on re-use of surplus food for human consumption for people affected by food poverty, through redistribution networks. Unavoidable food waste can be recycled into animal feed and composting. Unavoidable food waste is also increasingly viewed as a resource to be recovered, through technologies like Anaerobic Digestion (AD), into high-value energy, fuel, and natural nutrients as outlined in Bioenergy and Biofuels, and Biochemicals and Biomaterials sections above.

Construction

The Engineering & Construction sector is the largest global consumer of resources and raw materials. Estimates suggest that the sector generates approximately 30% of all waste generated annually in the EU. In response, the EU has established mandatory targets for the recycling of construction and demolition (C&D) waste.

The application of circular design strategies in the construction sector is being implemented, albeit on a relatively small scale. Circularity can be introduced into the sector through eco-design, the development of sustainable materials, and recycling and reuse. There is also the possibility to displace high energy intensive construction products with e.g. renewable carbon sources such as timber. Eco-design in the construction sector requires architects and engineers to consider the demolition phase during the design phase. The design of prefabricated or 3D printed components can also enable the reuse of components in refurbishment or new build projects.

Ireland has an established sector in manufacturing products and materials for the construction industry. In recent years a number of these companies have produced more sustainable products and materials servicing the Irish and export markets. One such company is Ecocem, which is a producer of low carbon cement.

Another key strategy in the context of the circular economy is tackling the underutilisation of existing buildings. Tackling the regulatory and legal blockage preventing vacant properties from being used could help reduce the resources required for the construction of new buildings.

Water Management

Prominent actors in Ireland with regard to the circular water economy include water utilities, wastewater treatment centres and large water users, including dairy producers and the beef industry.

The water sector is possibly the largest untapped sector in contributing to the circular economy worldwide. Globally, by 2030 nearly half the world's population will be living under conditions of severe water stress, yet less than 5% of all water is reused globally. Water scarcity has also worsened in some parts of the EU in recent decades, with damaging effects on the environment and economy. Existing water systems are often inefficient with water lost, polluted and wasted in what is still predominately a linear system from catchment to consumer.

The introduction of circular economy principles and practices of waste reduction, biobased processing, recycling and reuse is increasingly being applied to water management. A suite of interventions exists, ranging from water efficiency measures (sound water infrastructures, water meters, water conservation by consumers), reuse of treated wastewater (including industrial waste water recovery, water recovery from municipal waste water and sewage), water reuse in agriculture, and novel catchment solutions (rainwater harvesting and recycling).

The application of circular economy principles to water also includes heat recovery by, for example, using heat exchangers to extract energy from heated water from homes, sewers, or underground sources. Recovery of materials from waste water (e.g. industrial waste water) is another aspect of circular economy principles applied to water management.

Industrial Symbiosis, Eco-Towns, and Eco- Cities

Industrial symbiosis is a key strategy within both the circular economy and the bioeconomy. Industrial Symbiosis describes the physical exchange of resources such as materials, water,

energy and other by-products between companies. Typically, industrial symbiosis occurs between industries where the surplus or waste materials from one company becomes the input or feedstock for another. The UK National Industrial Symbiosis Programme has developed a network of 15,000 companies. The programme identified resource transactions between companies that were mutually beneficial and profitable. The programme has diverted more than 47 million tonnes of industrial waste from landfill.

SMILE is Ireland's Industrial Symbiosis programme and was launched on a preliminary basis in 2010 with funding from Cork County & City Council and Local Enterprise Office, South Cork. SMILE is a free online platform for industry through which synergies can be created between businesses that have surplus or unwanted materials and businesses that have a need for those materials. The platform has almost 1,500 members.

There is an increasing focus on the role of cities and towns in the development of the circular economy. Cities are the sites of critical infrastructures for biomass management, energy, water, waste, food consumption and transport, and are home to major actors including national government, utilities, city authorities, regulators, businesses, social enterprises, consumers, and civil society actors. The symbiosis needed in the circular economy between disparate actors is therefore possible within the city context. Eco-towns have also begun to play a particular role in the circular economy by acting as 'niche innovators' by implementing innovative practises that can potentially be scaled to national and international levels.

Figure 1 below, taken from the NESC report *Moving Towards the Circular Economy in Ireland* summarises the main actors in the circular economy here.

Supply side - creating circular economy outputs

Enterprise support

SMILE
Enterprise Ireland
EPA
IBEC
IDA
Local Authorities
Regional Waste Management Offices

Users & purchasers

BIA Foodcloud
BITC Members
Camara
Online resellers
Free Trade Ireland
Individuals, Bargain Hunters
Origin Green Members
Social Enterprises
Waste industry

Advocacy & awareness

Business in the Community
CRNI
DCCAE
EPA / NWPP / CRNI
Multinationals
NGOs
Regional Waste Management Offices
Repak
Waste industry

Demand side - creating demand

Policy & regulation

CRNI
DCCAE
EPA
Local Authorities
NGOs
WEEE Ireland

Finance & funding

DCCAE
Enterprise Ireland
Environment Fund
EPA
Local Authorities

Evidence & data

Enterprise Ireland
EPA
ESRI
IBEC
Local Authority Prevention Network
National Waste Collection Permit Office
Repak
Reuse Organisations
Universities
Waste industry

Governance - combination of push and pull

Leaders

BIA Foodcloud
Dublin Bike Scheme
Enrich Soil Solutions
Go Car
IAMECO
Rediscovery Centre
Rothar
Share Ireland
SMILE
Sunflower recycling

Skills & education

An Taisce
Clean Technology Centre
Eco Unesco
EPA / Green Schools
Rediscovery Centre
Rehab
Recreate
Social Enterprises

Research & knowledge exchange

Clean Technology Centre
Enterprise Ireland
EPA
Joint Programme Initiatives
NESC
Rx3
Universitiy of Limerick
UCD School Food and Biosystems Engineering

POLICY CONTEXT

International context

The circular economy has become a policy priority for the European Commission in recent years. The EU Circular Economy Package is at an advanced stage, following on from the publication of the European Commission's plan *Closing the Loop: An EU Action Plan for the Circular Economy*. The European Commission has also developed mandatory product design and marking requirements to make it easier and safer to dismantle, reuse and recycle electronic

displays (e.g. computer monitors, televisions and electronic display integrated in other products). In addition, European standardisation organisations are working to develop generic standards on the durability, reusability and recyclability of certain products.

As the European Commission points out, no set of indicators currently exists for monitoring and evaluating the Circular Economy transition that captures all the main elements of the circular economy along the lifecycle of materials, products and services. The European Academies' Science Advisory Council (EASAC) 2016 report on *Indicators for A Circular Economy* pointed to the priorities to be monitored. These include: decoupling of resource use and environmental impact from economic activities, measurement of resource efficiency and waste reduction, and tracking material flows. It identified many relevant indicators already available with respect to sustainable development, environment, material flows, societal behaviour, organisational behaviour and economic performance that could be directly applied to monitoring the transition to a circular economy.

Policy context in Ireland

The *Draft National Planning Framework, Ireland 2040: Our Plan*, includes a vision for Ireland to have a 'capacity for sustainable self-reliance based on a strong circular economy and significant progress towards a low-carbon, climate-resilient society'. However, as indicated in the introduction to this report, Ireland has yet to adopt a dedicated circular economy strategy.

INNOVATIONS FOR SUSTAINABILITY

Main innovations

The transition to the circular economy involves the introduction of circular economy principles aimed at reducing waste and maximising reuse across the most vital sectors that underpin the functioning of a modern society, including manufacturing, food, water, construction and waste management. The current systems that provide these vital functions are arranged largely on a linear 'make-use-dispose' basis. The transition to a circular economy will therefore be pervasive and involve a wide range of innovations affecting production, distribution, and consumption. Consumer attitudes and behaviours will play a major role in many aspects of the transition. In addition, facilitating the networks and pathways needed for material reuse across many diverse actors constitutes a major and critical challenge.

SUMMARY OF ENTERPRISE OPPORTUNITIES

The Circular Economy impacts on enterprises across the economy, from micro-enterprises to SMEs to large multinational firms. It encompasses a wide range of issues regarding the usage of materials, from inputs to manufacturing, manufacturing processes, packaging, waste management, water management, product design, recovery and reuse of materials, and consumer behaviour.

Companies can be categorised broadly as firms who are innovating in order to comply with regulation and standards with respect to the circular economy; a smaller cohort of firms who

are providing technology and services solutions; and lead innovators who are developing or adopting leading edge technologies and services solutions based on circular economy principles.

Surveys of SMEs in Ireland show that the main category of activity with regard to compliance is in the area of waste management. As this section shows, a smaller cohort of companies are also active in providing technology solutions for firms seeking to reduce waste and manage water usage. Among these technology solutions is the application of ICT to track materials use and to create symbiosis between firms in reuse and recycling.

In the development of the circular economy, lead innovators who are often large companies, can have a transformative effect on their value chain including their suppliers and customers by adopting circular economy principles as a core business model. The presence of such lead innovators in Ireland has not been identified from the research in this report.

A category of firms that is active in the circular economy but which receives less visibility in the innovation literature are social enterprises. Such enterprises typically generate employment at a local level, including in areas of social disadvantage.

3.2. The Sharing Economy

OVERVIEW

The sharing economy can be thought of as a subsystem within the circular economy. In both cases individuals reuse materials and goods that already exist in order to maximise use of existing resources. In both cases the environmental impacts associated with consumption can be reduced. The key difference is that in the circular economy, materials and goods are re-used, recycled or repaired. In the sharing economy, typically highly valuable goods are shared for short periods of time.

While there is no widely-accepted definition of the sharing economy (also referred to as the collaborative economy), the typical characteristics of the activities within the sharing economy have been identified. These are, operating through an online platform via a website or an app, that enables consumer-to-consumer transactions, that temporarily provides access to a good or service, with no transfer of ownership. This activities-based definition excludes the 'second-hand economy' in which goods are resold to utilise an under-used asset.

Presently, collaborative consumption is adopted most widely in car-sharing, accommodation, and in website-based networks sharing different products (music, textbooks, fashion, and art, among others). In general, consumers need to be located within a certain online community or geographical location for access to such schemes. Research shows that participation in the sharing economy is motivated by many factors such as sustainability concerns, link with leisure activities, as well as cost savings. Irish consumers are among the EU citizens most willing to use sharing platforms, with 35% of the public reporting to use at least some aspect of the sharing

economy. This is despite the relatively small economic value of the sector and its limited spread outside the accommodation sector in Ireland.

MAJOR ACTORS

Sharing Platforms

In the sharing economy, platforms link producers and consumers to provide services that make the sharing economy viable, including reduced cost and ease of access. For instance, listing an apartment on an accommodation platform can be done at little cost to providers, and allows potential customers to easily browse the multitude of offerings at no substantial cost to consumers.

The intermediation of a neutral third-party platform also mitigates the risks concerning economic transactions between strangers; the platform therefore builds the requisite trust for sharing economy services to function. Intermediaries also operate user rating systems to help users avoid counterparties with an untrustworthy track record. While most platforms are small to medium sized, a small handful of very large platforms dominate.

The sharing economy is heavily concentrated in a few sectors in Ireland, particularly accommodation sharing and car sharing. Accommodation is the biggest sector in the Irish collaborative economy both in terms of persons employed and revenue. The sector generated revenue of €67.5 million in 2016 and employed a total of 1,840 employees. It is dominated by Airbnb, which has its European headquarters in Dublin and has had a significant impact on the hospitality sector. Four domestic platforms also operate, specialising mainly in home-sharing.

The transport sector is currently Ireland's second most developed collaborative economy sector, with revenue of €50.2 million. Many cities worldwide have seen the development of car sharing schemes with the key rationale being the maximisation of utility of vehicles in the city by sharing across multiple users. The sector in Ireland comprises four platforms, of which three are domestically-owned and one foreign-owned. The sector provides around 870 jobs. Uber is restricted in Ireland to licenced taxi drivers and chauffeur-driven cars.

POLICY CONTEXT

International Context

There has been considerable public debate over the last number of years on the sharing economy. Adherents point to the savings that accrue to consumers and the potential environmental advantages of increased usage of underutilised assets. Detractors argue that it has created social problems, particularly in the housing sector. Several large cities that are major tourist destinations, such as Barcelona, Amsterdam and New York, have effectively banned short term lets over concerns that it has driven up rent for residents. In Ireland, Airbnb has also faced criticisms of exacerbating the rental crisis, by taking properties which would otherwise have been in the long-term rental market particularly in Dublin. Concerns have also arisen with regard to car sharing services as these may encourage people to move from mass public transport to individual car usage, contributing further to traffic congestion.

Regulatory issues are important in the context of the sharing economy. In 2016 the European Commission identified a range of issues stemming from regulatory 'grey-areas' owing to the blurred lines between consumers and providers, employed and self-employed workers, and the professional and non-professional provision of services. At the same time, the commission generally welcomed growth in the sector owing to its potential to contribute to the EU's sustainability agenda. Taxation collection is also an area of concern for the sharing economy. Issues include the uncertainty on tax classification of earnings (such as whether earnings are subject to income tax or not) and the fragmentation of sources of income. These issues increase compliance and administration costs.

As well as creating new markets and expanding existing ones, collaborative economy businesses enter markets so far served by traditional service providers. A key question for authorities and market operators alike is whether, and if so to what extent, under existing EU law, collaborative platforms and service providers can be subject to market access requirements. These can include business authorisations, licensing obligations, or minimum quality standard requirements.

INNOVATIONS FOR SUSTAINABILITY

Main innovations.

Sharing economy initiatives in transportation, housing/accommodation, sharing/renting of smaller capital goods and services could lead to reduced environmental impact. Transport is the sector where the potential for emissions reductions is largest, through CO2 emissions reductions from reduced driving of private cars and reduced car production. Reduced environmental impact through the sharing economy depends critically, however, on changes in individual behaviour leading to the widespread uptake of shared services. Behavioural innovation must therefore accompany technological innovation, investment in infrastructure and regulatory change in order to drive growth in the sharing economy.

SUMMARY OF ENTERPRISE OPPORTUNITIES

While the sharing economy can have a major impact on behaviour of masses of citizens, the platforms upon which the sharing economy operates are typically dominated by a small number of firms. Enterprise opportunities in this space are therefore typically restricted to lead innovators who develop or adopt leading edge technologies and services solutions based on sharing economy principles.

Section 4: Analysis and Policy Implications

4.1 Summary of Enterprise Opportunities in the Bioeconomy and Circular Economy

ENTERPRISE OPPORTUNITIES IN FOOD, FORESTRY AND MARINE

Ireland has an established enterprise base in agri-food, forestry and marine. Enterprise Ireland has an active client base and future opportunities have been identified in *Innovation 2020* and *Foodwise 2025*. These opportunities include firms providing processes and technologies which improve productivity and sustainability of production and food safety, and value-added products including food for health, nutraceuticals and functional foods and personalised nutrition. SFI and Enterprise Ireland research centres active in these areas include the Dairy Processing Technology Centre (DPTC), the Meat Technology Centre (MTC) and the EI Technology Gateway Shannon ABC in Applied Biotechnology.

The food, forestry and marine sectors will play a foundational role in the bioeconomy as a producer of the biomass that will underpin the other components of the bioeconomy. The challenges for actors in these sectors in this regard lies in the need to recognise biomass as an additional potential revenue stream, and for primary producers to become part of bioeconomy value chains.

ENTERPRISE OPPORTUNITIES IN BIOCHEMICALS AND BIOMATERIALS

The biomaterials and biochemicals component of the bioeconomy in Ireland is still very much in a nascent stage. The small number of companies active in this area are generally lead innovators who are innovating in multiple areas including developing technology, establishing value chains, and sourcing global markets. Experience to date suggests that the sectors most likely to participate in biomaterials and biochemicals part of the bioeconomy will be the food, biotechnology /pharmachemical, and energy industries.

The SFI Beacon Bioeconomy Research Centre is an important initiative in this area along with the Enterprise Ireland funded Irish Composites Centre (IComp) and the EI Technology Gateways APT in Polymer Technologies and SEAM in Applied Materials. The instigation of a Disruptive Technologies Innovation Fund, designed to support large scale demonstrations of disruptive technologies to address societal challenges, represents another important policy tool for potential use in supporting lead innovators in this component of the bioeconomy.

ENTERPRISE OPPORTUNITIES IN BIOENERGY AND BIOFUELS

The membership of the Irish Bioenergy Association, with around 140 members ranging from state owned companies to SMEs, illustrates the current enterprise base in bioenergy in Ireland. The challenges for many companies in both bioenergy and biofuels include sourcing sustainable

and reliable biomass and establishing value chains from biomass sourcing to market. Future scenarios show that Ireland's biofuels and bioenergy sectors may need to grow significantly in the future. The SFI MaREI research centre acts as a hub for research in bioenergy and biofuels and fosters collaborations with key industry partners in these areas.

ENTERPRISE OPPORTUNITIES IN THE 'MECHANICAL' CIRCULAR ECONOMY

The Circular Economy impacts on enterprises across the economy, from micro-enterprises to SMEs to large multinational firms. It encompasses a wide range of issues regarding the usage of materials, from inputs to manufacturing, manufacturing processes, packaging, waste management, water management, product design, recovery and reuse of materials, and consumer behaviour.

Companies can be categorised broadly as firms who are innovating in order to comply with regulation and standards with respect to the circular economy; a smaller cohort of firms who are providing technology and services solutions; and lead innovators who are developing or adopting leading edge technologies and services solutions based on circular economy principles.

Surveys of SMEs in Ireland show that the main category of activity with regard to compliance is in the area of waste management. The presence of such lead innovators in Ireland has not been identified from the research in this report. A category of firms that is active in the circular economy but which receives less visibility in the innovation literature are social enterprises. Such enterprises typically generate employment at a local level, including in areas of social disadvantage.

Irish Manufacturing Research (IMR) and the EI Technology Gateway PEM in Precision Engineering and Manufacturing are important research centres relevant to the mechanical circular economy.

ENTERPRISE OPPORTUNITIES IN THE SHARING ECONOMY

While the sharing economy can have a major impact on behaviour of masses of citizens, the platforms upon which the sharing economy operates are typically dominated by a small number of firms. Enterprise opportunities in this space are therefore typically restricted to lead innovators who develop or adopt leading edge technologies and services solutions based on sharing economy principles. This is currently restricted to a small number of companies in Ireland.

4.2 Realising the Opportunities for Enterprise

It is apparent from this analysis that the bioeconomy and circular economy present a broad range of current and potential opportunities for enterprise. These opportunities exist for firms ranging from micro-enterprises to SMEs to large firms. State owned and semi-state companies as well as social enterprises are also engaging with the opportunities presented.

It is clear, however, that many of these opportunities remain unrealised as yet, largely because of the current embryonic stage of both the bioeconomy and circular economy in Ireland. It is important therefore that enterprise policy remains cognisant of developments in these areas and responds to emerging opportunities as they arise.

A roadmap for realising the current and future opportunities in the bioeconomy is currently being developed by the Bioeconomy Implementation Group of which DBEI is an active member. The Bioeconomy Implementation Group (BIG) was established following the publication of the National Policy Statement on the Bioeconomy by the Department of an Taoiseach in March 2018 and tasked with advancing the key systemic and strategic actions in the policy statement.

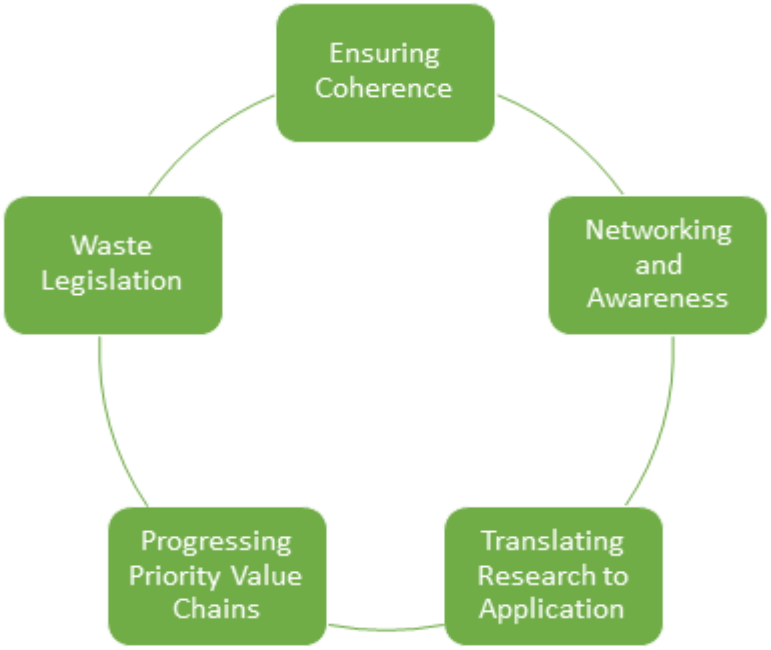
The BIG has adopted the framework recommended by the OECD for governing system wide change, such as that represented by the development of the bioeconomy and the circular economy. This system innovation framework is outlined in Figure 2 below, where the main points of the framework are listed along with the relevant actions being taken by the BIG.

Figure 2: System Innovation Framework being used by BIG

Ten Points for System Innovation		**BIG Actions**
1	Developing a vision	The National Policy Statement on the Bioeconomy forms the basis for Ireland's vision of the future bioeconomy
2	Building collective leadership capacity	The Bioeconomy Implementation Group (BIG) spans government Departments and agencies; the Irish Bioeconomy Forum, comprised of public and private stakeholders, will advise BIG
3	Coordinating across Government	Review of strategies across government is being conducted to ensure coherence
4	Lengthening planning and investment horizons	Actions are being progressed under longer timelines established by the National Planning Framework and associated Regional Development Plans
5	Establishing collaborative partnerships for co-investment	BIG seeks to establish partnerships under H2020, biocluster policies, and demonstrator projects funded on public-private partnership model
6	Engaging private and state-owned companies	BIG is engaging with private and semi-state actors active in bioeconomy innovation including e.g. BioEnergy Ireland

7	Encouraging technological and non-technological innovation	BIG is exploring initiatives in other countries e.g. Green deals in Netherlands and BioNets ecosystems in Finland
8	Overcoming resistance of incumbent industries and reluctant citizens	Policies must stimulate structural change including scaleup of niche innovations and growth of transformative lead innovators
9	Focus on international collaboration	Alignment with European policy including EU KIC & Innovation Council activities
10	Evaluation to gauge progress and steer the system	Annual BIG report to government

In addition, BIG has distilled the key actions in the National Policy Statement on the Bioeconomy into five action areas, all of which are being progressed in parallel, as illustrated below.



The broad system innovation framework being used by BIG, together with the five action areas outlined, provide the roadmap for progressing existing and potential opportunities for enterprise in the bioeconomy.

Specific actions being taken in this regard include:

- The review of coherence of strategies and policy instruments being carried out by BIG across government will highlight areas where additional support may be needed to support firms and advance the development of the bioeconomy
- The networking and awareness activities of BIG crucially include firms engaged in the bioeconomy across all the components described in this report. These networking activities will act as a source of knowledge for additional actions needed to support firms
- DBEI and its agencies are playing a key role in the translating research to application activities of BIG. Further actions needed will be identified by DBEI and its agencies in partnership with the other members of BIG
- Progressing priority value chains is a central action for progressing the development of the bioeconomy. The innovation supports of DBEI and its agencies will be of crucial importance here, along with funding from other Departments and agencies, as well as EU funding. The Disruptive Technologies Fund also has a potentially significant role to play in this regard
- DBEI will input to the work of BIG with respect to waste legislation as appropriate.

Given the wide range of enterprises engaged or with the potential to engage with the bioeconomy and circular economy, the general principles and actions outlined here will need to be applied to firms on a case by case basis appropriate to their needs. This is expected to be particularly the case for transformative leading-edge innovators as their number in a country of Ireland's size is expected to be relatively small.

4.3 Enterprise Policy for the Bioeconomy and Circular Economy

In addition to engaging with the cross-government initiative on the bioeconomy through the Bioeconomy Implementation Group, the following three possible actions which have emerged from the research from this report could be examined in more detail.

1. *An increased focus on adoption and diffusion of existing technologies*
   Ireland appears to be behind comparison countries with regard to the adoption of existing technologies in both the bioeconomy and the circular economy. An increased focus on the adoption and diffusion of existing technologies and practices could accelerate the development of the bioeconomy and circular economy here.
2. *Catalysing transformative lead innovators*
   Lead innovators can play a major role in transforming value chains when they adopt new technologies and practices. In doing so, they can induce suppliers and customers to innovate in ways which can have a significant impact in terms of the development of the bioeconomy and circular economy as a whole. Further research on the role of such transformative lead innovators is warranted, along with an analysis of the policies that can be adopted to encourage the emergence of a greater number of lead innovators in Ireland.

3. *Specific action needed on Circular economy*
   The bioeconomy is an active area of research, policy and enterprise engagement in Ireland. The circular economy, by comparison, is still very much at a nascent stage. A strategic whole of government response is needed to facilitate the development of the circular economy here.