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CIRCULÉIRE's Thematic Working Group

Circular Plastics 2021
Summary Report

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This Circular Plastics (2021) Summary Report provides an overview of key findings from the Circular Plastics (2021) Comprehensive Synthesis Report - please refer to the Synthesis report for more detailed insights into the Irish Circular Plastics landscape.

IRISH MANUFACTURING RESEARCH

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About CIRCULÉIRE

CIRCULÉIRE, the National Platform for Circular Manufacturing seeks to accelerate Ireland's transition towards a net-zero carbon circular economy. A key objective of the programme is to demystify, de-risk and deliver circular business model innovation for Irish industry. A Circular Plastics Thematic Working Group was established in 2021 with representing industry, solution providers, academia and policy actors in Ireland. The two objectives of the working group were: to produce a state-of-the-art review to understand best practice (practice and policy) from further afield to inform how to address gaps and barriers in Ireland, and to develop recommendations for circular innovation projects (that are systems innovations) with potential to be funded by CIRCULÉIRE's Innovation Fund and rolled out across Ireland.

Want to learn more about CIRCULÉIRE? Look at www.circuleire.ie, or contact circuleire@imr.ie

Disclaimer

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Executive Summary

CIRCULÉIRE[1], the commissioner of this report, is a public-private partnership created by Irish Manufacturing Research and the Department of the Environment, Climate and Communications (DECC), the Environmental Protection Agency (EPA), and EIT Climate-KIC with a growing network of cross-sectoral Industry Members. It is the first industry-led innovation network in Ireland dedicated to accelerating the net-zero carbon circular economy in Ireland. Underpinned by systems innovation and utilising a ring-fenced network innovation fund, CIRCULÉIRE will foster innovative collaboration do drive the transition to a zero-carbon circular economy, providing up to date information, such as that contained in this report, to inform both members and the wider Irish innovation ecosystem.

The primary goal of this report is to inform readers of the potential for and development towards a Circular Plastics economy in Ireland, through an analysis of policy and best practice and the development of innovation demonstrator opportunities [2] that can further the circular plastics economy in Ireland. It does not include a comprehensive mapping of the polymer industry in Ireland, nor does it quantify the economic potential associated with the sector. Indeed, it is a recommendation of this report that such a mapping is required for future planning. While the scope of this report includes packaging it primarily focuses on other plastics value and waste streams, so as to avoid duplication with the CIRCULÉIRE Thematic Working Group on Circular Packaging and Reusables (2021) [3] , which considered opportunities to circularise plastic packaging within its scope.

National Context: The Environmental Protection Agency (EPA) provides official statistics on waste generation and management in Ireland. In Ireland, current recycling rate for plastic (2019) is around 28% including exports for recycling to other countries. While Ireland meets current EU requirements and has achieved high recycling rates in some packaging material streams, in particular glass, paper and cardboard, there has been an overall gradual fall in polymer recycling rates over recent years, from 74% in 2012 to 62% in 2019. Ireland's recycling rate for plastic has dropped for the third year in a row to 28% in 2018. Plastic packaging waste incinerated for energy recovery has grown year on year from 44% in 2017 to 69% in 2019. Based on these trends, the much higher EU recycling targets that will apply from 2025 and 2030 are likely to pose significant challenges for Ireland.

General Context: The use of plastics has grown substantially over the past 70 years and today plastics are found in wide-ranging applications, both commercial and domestic. The historical success of plastics as a material has been widespread: its range of forms, from natural polymers, modified natural polymers, thermosetting plastics & thermoplastics, coupled with its unique properties such as chemical and moisture resistance, toughness, relative freedom from environmental stress offers many societal benefits for health and safety.

[1] CIRCULÉIRE - The National Platform for Circular Manufacturing in Ireland. (n.d.). Retrieved September 13, 2021, from https://circuleire.ie/

[2] The TWG used the criteria of CIRCULEIRE's Innovation Fund to help set the scope of the demonstrator opportunities i.e. 12-month industry-led Circular Plastics demo pilots, with an estimated cost of between 50 – 250K, and with potential to address Ireland's GHG and waste reduction targets if successfully scaled.

[3] See more at: CIRCULÉIRE (2021) Circular Packaging TWG Summary Report. https://wks.circuleire.ie/public/artefact/2a2816f8-aaa0-488f-9505-400bc3bcc5db

Plastics are categorised into 7 major categories, PET, HDPE, PVC, LDPE, PP, PS and 'other'. However, there are at present a known fifty thousand resin types that exist which are an amalgamation of any number of plastic types and it is this complexity that has, to some extent, led to the difficulties in circularising the plastics value chain. PET and HDPE, for example, lend themselves to reuse and mechanical recycling due to their relative simplicity and high-quality material.

Meanwhile, other mixed plastics pose a greater technical challenge for mechanical recycling and are thus often disposed of after their intended use. Additives and adhesives make revalorisation even more challenging. Among plastics that are designed for disposal, the impact of a plastic material type depends on its time in use— some are made for single use while others are designed for longer-lasting applications (like Tupperware), increasing their life cycle and reducing their environmental impact when considered over time. Design for recycling is a key requirement for materials in order to meet recyclability and broader sustainability goals.

This Summary Report provides an overview of the key findings and outputs of CIRCULÉIRE's (2021) Circular Plastics Thematic Working Group, which took place over three months. Consisting of 20 panel members from industry, solution providers, academia and research, industry representatives, compliance bodies and third sector representatives, this group examined the status of the Irish Circular Plastics landscape with a view to providing ideas for circular plastics innovation demonstrator projects with potential to make considerable GHG and waste reductions if scaled – and which could be funded through CIRCULÉIRE's ring-fenced network Innovation Fund or via other funding opportunities (e.g. Horizon Europe).

The key innovation opportunities identified by the panel members include:

- Laboratory Lab Waste reprocessed into reusable lab plastic items or re-used
- Develop and demonstrate a reusable cup scheme which could be rolled out nationally.
- Fish-Box redesign project- redesign Expanded Polystrene (EPS) boxes so they can be easily stacked for transport and can fulfil multiple functions.
- Recyclability of meat packaging- Determine levels of Ethylene-vinyl alcohol copolymer (EVOH) in meat packaging which maintains optimal barrier properties but allows ease of recycling of the packaging post use.
- Cleaning single use bioreactors for reuse
- Collection, decontamination and reuse of PPE
- Processing of thermoset waste with concrete
- Collect and repurpose other fishing related materials- Marine plastic to cleaning bottle plastic

While several of the innovation opportunities focus on recycling - a recognised transition strategy – the working group nonetheless acknowledged that focusing on collection, sorting, and recycling alone will not be enough to enable us to meet EU waste reduction targets. Other innovation opportunities focused on 'reuse' and 'redesign'. While recycling innovations will play an important role, it is hoped that ongoing efforts to circularise Ireland's plastic economy will continue to focus on 'R' strategies higher up the waste hierarchy.[4]

Building on discussions with Thematic Working Group Members during 2021, and a review of

[4] Other 'R' Strategies on the Waste Hierarchy are: Rethink/Redesign, Reduce, Reuse, Recycle and Recovery (considered the least acceptable strategy).

other jurisdictions where the stimulation of the Circular Plastics Sector represents similar challenges, the following potential areas of future focus for the development of the Irish Circular Plastics sector in Ireland were identified:

- **The adoption and/or acknowledgement of the benefits of circular plastics in relevant national policy, legislation, support schemes,** etc. - a need for more structured methodology that supports evidence-informed policy (to consider benefits, but also challenges, risks and opportunities and the development of such a mechanism to quantify these benefits that is supported by all stakeholders.

- **The identification of target applications where most value can be realised from the utilisation of circular plastics**, be this as feedstock material, an additive, etc. in order that engagement, investment, marketing etc. can be focussed on the development of products relevant for these specific applications. order that engagement, investment, marketing etc. can be focussed on the development of products relevant for these specific applications.

- **The requirement to raise the profile of circular plastics as a product amongst potential end users through, among other things, the continued undertaking and catalysing of circular demonstration projects**, such as stimulated by the CIRCULÉIRE Innovation Fund to which this study is related, and the promotion of the findings of such studies.

- **Continued collaboration between relevant stakeholders** to build on the significant activities undertaken to date in the circular plastics sector, to utilise resources, experience, contacts, lobbying abilities etc. - **the preparation of a National Circular Plastics Development Plan or Action Group**, led by an appropriate organisation and supported by relevant governmental department(s), that ties in the various activities and projects currently ongoing, **could be a central 'driver' in sectoral development.**

1 Introduction

Key Messages:

- Plastics are classified into 7 major categories, PET, HDPE, PVC, LDPE, PP, PS and 'other'. However, there are at present a known fifty thousand resin types that exist which are a combination of any number of plastic types and it is this complexity that has, in some way, led to the difficulties in circularising the plastics value chain.
- Recent years have seen heightened interest in the potential of circular technologies to break, or at least mitigate, the adverse effects of the linear "take-make-use-dispose" model.
- The concept of Circular Plastics is that of a new plastics paradigm, along the value chain from design to reuse, in which resources related to plastics and polymers are reused and revalorized. Instead of making new products from virgin materials, a product's end life is taken into consideration, and new sustainable, recycled materials become a viable alternative to conventional virgin plastic.

1.1 General Context

Plastic is a highly versatile material. It is lightweight, functional, durable and, among other things, has been critical in the National and EU COVID-19 emergency response through its use in the manufacture of personal protective equipment (PPE). However, 'plastic' should not be understood as a catch-all term: each plastic consists of one or more polymer types and may contain other substances such as additives (colours, antimicrobials etc), fillers, and characteristic modifiers such as phthalates (modify rheological properties).

Polymers are listed as category types, each with its own characteristics, usage and demand rates[5]: Numbers 1-6 list the main category types and the 7th, O*ther*, is an is an umbrella term covering all other kinds of plastics, not fitting in the other categories. Products are made from one or more of the categories, and resin mixes are dependent upon producer characteristic requirements. This demand for a high-variety of products has led to troubling complexities in the makeup of plastic products that make end of life treatments for some products incredibly difficult.

1.2 Waste

One thing that most plastics have in common is that they are incredibly slow to decompose. In contrast to naturally occurring polymers, such as silk, cellulose and DNA, synthetic plastics currently cannot easily be broken down by weathering processes and microorganisms, leading to prevalent environmental pollution: the resistance to biodegradation has invariably resulted in the presence of microplastics in fish or drinking water, and plastic litter clogging up sewers has amplified the risk of flooding, contamination and vector-borne diseases.

In terms of plastics value as a 'waste' product (both post-industrial and post-consumer), only a few polymer types are traded due to their high volumes and relatively low cost: Low-density polyethylene (LDPE), high-density PE (HDPE), polypropylene (PP), PVC, PS and polyethylene terephthalate (PET) account for approximately 90 per cent of the global total demand. Global trade in plastic waste, meanwhile, is small relative to overall plastic waste generation: The Organisation

[5] PlasticsEurope. (2020). Plastics-the Facts 2020 An analysis of European plastics production, demand and waste data.26.

for Economic Co-operation and Development (OECD) found that, in 2015, just 4% of the 300 million tonnes of plastic waste generated was exported outside the country of origin.

1.3 Circular Plastics

The concept of Circular Plastics is that of a new plastics paradigm, along the value chain from design to reuse, in which resources related to plastics and polymers are reused and revalorized instead of being virgin produced, a product's end life is taken into consideration, and new sustainable materials become a viable alternative to conventional plastic. The plastics value chain spans production to consumption and disposal and involves varied actors along the way who present differing challenges and opportunities: at all points of the value chain, there is an element of perceived benefits which differs across actors.

New EU Directives and an increasingly eco-conscious industry and public are driving major brands to reduce their carbon footprint and include rising percentages of recycled plastics within products such as plastic bottles. The growth in demand for plastic products and packaging combined with rising knowledge of environmental concerns, are among the main drivers for plastic circularity. This will translate into strong growth for the industry, with estimates of compound annual growth rates (CAGRs) between 5.00% and 7.90% between 2018 to 2026. The market in 2017 is valued at US$348 billion, with some analysts predicting a larger market with a value of US$669 billion by 2025[6]. Expected growth is likely to positively impact all major end-uses and plastic resin-types. The market can be segmented into three major end-users: packaging accounting for 69% of the market, construction accounting for 14%, and the automotive industry accounting for 8%. The global recycled plastic market is dominated by four major plastic resin types, namely PET, accounting for 55% of the market, HDPE accounting for 33%, and PP and LDPE both accounting for 4%.

The highest impact market challenges appear to be inefficient waste segregation and waste management problems. Regarding market positions: India, China and Hong Kong are considered the cheapest sources for virgin materials, and other regions will have to match these prices to remain competitive. From a quality perspective Virgin resins compete aggressively on price and quality/consistency when compared with recycled resins. However, this offers opportunities for technical innovations to increase the value of recycled plastics through improved sorting (which reduces contamination), new methods that make use of low value/underutilised feedstocks, and technologies for higher quality recycled resins to compete with virgin resins. These advances would intensify competition and there is space for integrating changes along the supply chain.

1.4 Concepts related to Circular Plastics

1.4.1 Circular economy

The concept of a circular economy has developed since the 1970, first integrating the ideas of limiting resource consumption to then incorporate closed loop systems thinking. Since 2010, with the increasing attention to pollution, greenhouse gas emissions and resource depletion, circular economy has become a central part of the strategic objectives to achieve climate change goals and carbon emissions reduction targets. For the purposes of this report, we align

[6] https://www.grandviewresearch.com/industry-analysis/plastic-packaging-market

to the definition of a circular economy for plastics as defined by the Ellen McArthur Foundation:

> *The circular economy is an economic system in which materials are designed to be used, not used up. From the outset, products and the systems they sit within should be designed to ensure no materials are lost, no toxins are leaked, and the maximum use is achieved from every process, material, and component. If applied correctly, the circular economy benefits society, the environment, and the economy*[7]

Transitioning to a circular economy does not only require adjustments to reduce the negative impacts of the traditional linear economy. Rather, it represents a paradigm systemic shift that builds long-term resilience, generates sustainable business and economic opportunities, and provides simultaneous environmental and societal benefits. The importance of all economic sectors needing to work together effectively, with expanded knowledge at all levels is recognised – both for large and small businesses, for organisations and individuals, nationally and locally. Below we elaborate on a number of concepts deemed fundamental to the achievement of a circular economy for plastics.

1.4.2 Bio economy

The concept of circular economy is closely related to the concept of the bioeconomy, which "should promote circularity through solutions and innovations that reuse and recycle materials, maximising resource efficiency through the use of unavoidable wastes and environmental sustainability." [8] The European Commission describes a bioeconomy as involving "the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy." (European Commission 2012). The EC promises to:

I. introduce healthy, safe and nutritious food, resource efficient and healthy animal feed, new food supplements;
II. provide new chemicals, building-blocks and polymers and other materials with new functionalities and properties;
III. provide bioenergy and biofuels replacing fossil energy;
IV. develop new, more efficient and sustainable agricultural and marine practices, improved bio-processing and biorefinery concepts, new process technologies such as industrial biotechnology;
V. deliver solutions for Green and Sustainable Chemistry;

1.4.3 Zero Waste Hierarchy

Value preservation is essentially a simple concept premised upon making products and packaging materials stay in the economy for longer, not as waste, but as viable materials and products. Designing waste out of the system by influencing consumption habits, rethinking business models and making them waste-free by design is the milestone of the zero-waste hierarchy. Further down the hierarchy, a new approach to the disposal of waste is proposed, replacing the

[7] Plastics and the circular economy. (n.d.). Retrieved September 02, 2021, from https://archive.ellenmacarthurfoundation.org/explore/plastics-and-the-circular-economy

[8] National Policy Statement on the Bioeconomy. 2018. Available online: https://assets.gov.ie/2244/241018115730-41d795e366bf4000a6bc0b69a136bda4.pdf

energy recovery vector with cost-effectiveness, value preservation, which also liaises with better energy efficiency, given the much lower energetic intensity of reuse and recycling relative to incineration and disposal and above all flexibility. The Zero Waste hierarchy has 7 levels, all of which pertain to supporting the transition to a circular economy for plastics. Two related to products and 5 related to waste: Refuse, Rethink, Redesign, Preparation for Reuse, Recycling, Composting Anaerobic Digestion, Materia land Chemical Recovery, Residuals Management, Unacceptable. strategies at the top of the waste hierarchy (e.g. rethink / reuse) are most preferable, while strategies at the bottom e.g. residuals management are least preferable in terms of reducing waste and GHGs.

1.4.4 Plastic Waste Management

Regarding plastic waste management, outside of reducing the amount of waste generated, reusing plastics is the current best alternative. Leakage of plastic waste into the environment is the least desirable, and disposal in landfills is only marginally preferable. Various stakeholder groups are actively pursuing initiatives to push waste management practices toward the upper end of the hierarchy. The immediate concern is to avoid plastics entering the environment, in particular marine pollution by plastics. For regions with established collection systems, an intermediate target is to find ways to reduce the use of landfills and incineration, which amplifies importance of pursuing strategies found higher up the zero waste hierarchy, such as reduction, reuse, recycling, and regeneration. While the hierarchy of plastic waste management provides high-level guidance on which type of recycling is preferable, local specifications need to be considered on a case-by-case basis.

1.5 General Challenges facing Plastics in the Circular Economy Value Chain

Current legislative encouragement for recycling: a legally binding directive of the European Union (EU) states that all plastic packaging shall be recyclable in a cost-effective manner or reusable by 2030 and aims at making recycling profitable for businesses. This upcoming legislation change in the EU will force EU packaging manufacturers to include a minimum of 25% recycled content in PET packaging from 2025. It also fixes a new target of 55% recycling of plastic packaging waste by 2030, sets a ban on landfilling separately collected waste and fixes stronger arrangements for extended producer responsibility (EPR) schemes.

Problem with designed polymer efficiency vs complications for recycling: advanced functionality such as embedded electronics, oxygen barrier layers and other innovative technologies have the unfortunate downside of decreasing the product value in a recycled stream, because separations are difficult and costly.

Physical Recycling as a method of plastic waste management: mechanical recycling is still currently deemed by many commentators to be "the most effective method to recycle plastics – in terms of time, economic cost, carbon footprint and environmental impact." [9] However, it is unlikely to hold the answer to sustainable or adequate plastic circularity for an array of logistical, scientific, and economic reasons. Successful plastics revalorisation requires a multifaceted approach, including the need for

[9] Mechanical Recycling of Packaging Plastics: A Review - Schyns - 2021 - Macromolecular Rapid Communications - Wiley Online Library

infrastructure to support novel ways to handle plastics e.g. chem recycling / biological recycling.

Technical Choice: One of the reasons for the low use of recycled plastics is the legitimate concerns of many manufacturers, particularly in highly regulated sectors such as pharma, medical devices and food contact applications who fear that recycled plastics will not meet their needs for a reliable, high-volume supply of materials with constant quality specifications, and Also due to the lack of a standard for such material

Cost of Virgin v recycled: Over 99% of plastics are produced from chemicals sourced from fossil fuels[10]. As such the cost of plastics is intrinsically linked to the price of crude oil. Recent drops in the price of crude oil have led to the price of commodity plastics such as PET dropping to $500-$600 per tonne whereas the price of recycled PET is ca $1,000 per tonne[11].

Efficient E-LCSA (Environmental Life Cycle Social Analysis): Limited LCA data available for assessment: In particular, this concerns equipment sizing which is required in standard approaches for determining investment and operating costs. An E-LCSA model is needed which could lead to satisfactory estimates of techno-economic parameters for plastics circularity efforts and more standardisation and guidance is needed to ensure that wider industry is effectively supported to undertake carbon calculations

[10] The Production of Plastic and Petrochemical Feedstocks. (2017). http://revenuesandprofits.com/how-exxonmobil-makes-money/

[11] https://www.grandviewresearch.com/industry-analysis/plastic-packaging-market

2 EU Policy Review

2.1 EU Policy Supports and Directives

Europe has a number of Union policies that support circular plastics to a lesser or greater degree, as summarised below.

Table 1: EU Policy Supports and Directives relating to Circular Plastics

Title and Year	Year	Description
ELV Directive	2000	Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles
EU Packaging and Waste Directive	1994 / 2018	This Directive covers all packaging placed on the market in the Community and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used
EU Waste Framework	2008 / 2018	Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (Text with EEA relevance)
WEEE Directive	2012/2018	Applies to all electronic and electrical equipment
European Battery Alliance (EBA)	2017	Supported by the Commission and the European Investment Bank (EIB), the EBA brings together EU national authorities, regions, industry research institutes and stakeholders in the battery value chain.
Circular Economy Legislative Package	2018	Revisions to the Waste Framework Directive (WFD) and the PPWD.
EU Plastics Strategy	2018	The EU adopted a European strategy for plastics in January 2018. It is part of the EU's circular economy action plan, and builds on existing measures to reduce plastic waste.
EU Bioeconomy strategy, 2018	2018	Strengthening the connection between economy, society and the environment
The EU Strategy for Plastics in a Circular Economy, 2018	2018	This strategy lays the foundations to a new plastics economy, where the design and production of plastics and plastic products fully respect reuse, repair and recycling needs and more sustainable materials are developed and promoted
EU Single Use Plastics Directive	2019	(EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment
EU Circular Plastics Alliance (CPA)	2019	Industrial alliance of full plastics value chain (c.300 organisations) representing industry, academia, public authorities committed to boosting EU market for recycled plastics by 10m tonnes by 2025.
EU Circular Economy Plan	2020	A New Circular Economy Action Plan for a cleaner and more competitive Europe.
EU Green Deal	2020	In addition to action plans/directives listed includes the: Sustainable Blue Economy; Zero Pollution Action Plan & Organic Action Plan
European Climate Pact (2020)	2020	The European Climate Pact is an EU-wide initiative inviting people, communities and organisations to participate in climate action and build a greener Europe through knowledge sharing, learning about climate change and developing and implementing solutions.
EU Policy Framework on biobased, biodegradable and compostable plastics	2021	Forthcoming EU initiative aims to promote bio-based, biodegradable and compostable plastics that lead to genuine environmental benefits. The initiative aims to contribute to a sustainable plastics economy.

2.2 Notable Associations and Actions in Europe

In Europe, the plastics industry which includes polymer producers is represented by Plastics Europe, converters are represented by European Plastics Converters (EuPC) and machine manufacturers are represented by EUROMAP, Europe's Association for plastics and rubber machinery manufacturers. Throughout the European Union, Plastics Europe engages with national plastics associations to strengthen the voice of the plastics industry and to ensure a coherent approach to the challenges the polymer industry faces. With a projected contribution of 1,2 Mt of recycled plastics produced through chemical recycling by 2025, Plastics Europe plays a leading role in delivering on the European Commission's Circular Plastics Alliance target of 10 Mt recycled plastics used in European products by 2025. Other associations include: Monitoring Recyclates for Europe (MORE), PolyCert Europe, Converters (EuPC), European Carpet and Rug Association (ECRA), European Single-ply Waterproofing Membranes Association (ESWA), Centexbel, Valipac, Waste Free Oceans, essenscia (BE), Unionplast (IT), Polyvia (FR) and NRK (NL).

3 Irish Policy and Performance

Ireland's performance:

- The Environmental Protection Agency (EPA) provides official statistics on waste generation and management in Ireland. Data from 2019 highlights that the current recycling rate for plastic is around 28%, including exports for recycling to other countries.
- While Ireland meets current EU requirements and has achieved high recycling rates for some packaging material streams, particularly glass, paper and cardboard, there has been an overall gradual reduction in polymer recycling rates, from 74% in 2012 to 62% in 2019.
- Ireland's recycling rate for plastic has dropped for the third year in a row to 28% in 2019. Plastic packaging waste incinerated for energy recovery has grown year on year from 44% (2017) to 69% (2019).
- Based on these trends, the much higher EU recycling targets that will apply from 2025 and 2030 are

3.1 Recycling performance in the Irish Landscape

The Environmental Protection Agency (EPA) provides official statistics on waste generation and management in Ireland. In Ireland, the current recycling rate for plastic (2019) is around 28% including exports for recycling to other countries. While Ireland meets current EU requirements and has achieved high recycling rates for some packaging material streams, in particular glass, paper and cardboard, there has been an overall gradual reduction in overall polymer recycling rates over recent years, from 74% in 2012 to 62% in 2019 and Ireland's recycling rate specifically for plastic packaging waste has dropped for the third year in a row to 28% in 2018. Plastic packaging waste incinerated for energy recovery has grown year on year from 44% in 2017 to 69% in 2019. Based on these trends, the much higher EU recycling targets that will apply from 2025 and 2030 will be challenging for Ireland.

The EU-level actions taken so far have focused on supply-side measures aimed at addressing

negative impacts of products, services and production, and on dealing with materials that become waste. While both are critical, it is unlikely that supply-side tweaks alone will achieve the scale of change required in the time available. Instead, there is a need to not only address what we consume, but also the way we consume, how much and why. With the exceptions of consumer information tools such as ecolabelling and voluntary green public procurement criteria, there are limits to how far EU level policy can go on demand-oriented policy instruments due to the current balance of policy responsibilities between the EU and the Member States. It is therefore up to each Member State to take the policy lead from the EU and adopt national strategies that incorporate all stakeholders to adopt circular economy practices. In Ireland, policymakers are increasingly turning their attention towards policies that improve revalorisation economics and support the creation of markets for circular plastics. The following are the most relevant to circular plastics:

Table 2: Irish Policies relevant to Circular Plastics

Title and Year	Description	Main points
Climate Action Plan, 2021	The recently published Climate Action and Low Carbon Development (Amendment) Bill 2021 presents an opportunity to streamline all national policies and frameworks under the goals of the circular economy that can support consumers, businesses and industry stakeholders to adapt sustainable circular practices	Ireland has committed to reduce the impacts of single-use plastics, reduce our waste to landfill to 10% by 2030 and reduce our food waste by 50% over the next 10 years. At present, we landfill almost 26% of our waste, 32% is incinerated for energy recovery and 41% is recycled or composted.
National Policy Statement on Bioeconomy, 2018	Overseen by a Bioeconomy Implementation Group, jointly chaired by the Department of Agriculture, Food and Marine (DAFM) and Department of Environment, Climate and Communications (DECC), the first progress report of the group highlights the actions required to move to an Irish Bioeconomy.	The implementation group, consisting of eleven Departments and eight agencies, met for the first time in May 2018 and has met on four further occasions in July, October and November 2018, May 2019. There have also been meetings in June, July and September 2021
Circular Economy Legislative Package from 2018	2020 saw the transposition of a number of key EU packaging and waste directives into Irish law.	The updated recycling targets for packaging and plastics included in the EU Packaging & Packaging Waste Directive are now enshrined in the Waste Management (Packaging) Regulations (SI 322/2020). Ireland must now recycle 65% of all packaging by 2025 increasing to 70% by 2030 and must meet a recycling target of 50% for plastic packaging by 2025 increasing to 55% by 2030
Waste Action Plan for a Circular Economy	Designed to replace the previous national waste policy, A Resource Opportunity – Waste Management in Ireland,	Overarching aim is to shift away from the current focus on waste disposal and treatment to ensure materials and products remain in productive use for longer. This is intended to prevent the build-up of waste and support the re-use of goods and materials in line with the new EU directives and the promotion of the circular economy. With over 200 actions, the Irish plan echoes many of the ambitions committed to in the European

Title and Year	Description	Main points
		Commission's Green Deal, particularly the goals of the EU's CEAP and acknowledges the challenges in meeting the EU Targets for packaging and recycling by 2025 and 2030
Whole of Government Circular Economy Strategy	The Programme for Government commits to a range of actions that will support the transition to a circular economy.	The preparation of a high-level whole of Government Circular Economy Strategy is underway and consultations on the preparation of the strategy have been completed The Circular Economy Bill will put the Circular Economy Strategy on a statutory footing, and implement many of the actions in the Government's Waste Action Plan for a Circular Economy. One of the interesting articles in the general scheme documents notes that the Government will have powers to impose product levies and bans on products which are deemed to disrupt the circular economy, though regulation would have to be approved through the normal legislative process. Perhaps most significantly, under Head 6, 14(a), the Bill also gives the Minister and Government powers to extend the list of products which can be either levied or banned
Single Use Plastic Directive	Regulations to give effect to this prohibition were signed by Minister Eamon Ryan on 3rd July 2021.	Ensuring the following SUP items are banned from being placed on the Irish market from 3 July 2021: Cotton Bud Sticks, Cutlery, Plates, Stirrers, Chopsticks, Straws, Expanded polystyrene single use food, and beverage containers, All oxo-degradable plastic products. Beverage containers (bottles, cartons) up to 3 litres in size will be banned from the Irish market from 3 July 2024, unless its cap is attached to the main part of the container. Beverage producers will also be prohibited from placing any SUP polyethylene terephthalate (PET) bottle up to 3 litres in size on the Irish market from January 2025 unless it contains a minimum of 25% recycled plastic. From January 2030 these bottles must contain a minimum of 30% recycled plastic.

4 Circular Plastics in the Irish Economy

Ireland's Circular Plastic's potential advantages:

- Several research centres in Ireland are involved in the circular economy and polymer technologies, focused on new and better product development, innovative technologies and solutions and supporting companies in their drive towards sustainability
- A growing area of expertise in Ireland is in chemical recycling which may offer some potential for difficult to recycle plastics/polymer streams as a supplement or replacement for mechanical recycling.
- We have plenty of waste as feedstock.

The New Plastics Economy defines a circular economy for plastics as having 6 essential goals[12]:

- Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority
- Reuse models are applied where relevant, reducing the need for single-use packaging
- All plastic packaging is 100% reusable, recyclable, or compostable
- All plastic packaging is reused, recycled, or composted in practice
- The use of plastic is fully decoupled from the consumption of finite resources
- All plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected

If we use these characteristics as a target aspiration, it becomes clear that Ireland has a long way to go to developing a whole closed loop system that is restorative and regenerative by design. However, a number of actions and guidelines have been implemented and the working group felt that the concept of circular economy is gaining traction.

4.1 Global Market opportunities

The growth in demand for plastic products and packaging combined with rising knowledge of environmental concerns, are the main drivers for plastic circularity. This will translate into strong growth for the industry, with estimates of compound annual growth rates (CAGRs) between 5.00% and 7.90% between 2018 to 2026[13]. The market in 2017 is valued at US$34.8 billion[3], with some analysts predicting a larger market with a value of US$66.9 billion by 2025[14]. The highest impact **market drivers** identified are growing environmental concerns and sustainability goals, an increase in rate of plastic recycling, emerging opportunities and growing demand for recycled products and increased regulation and government support. The highest impact market challenges appear to be inefficient waste segregation and waste management problems. Regarding **market positions:** India, China and Hong Kong are considered the cheapest sources, and other regions will have to match these prices to remain competitive. A challenge in looking to pursue a circular economy for plastics is that virgin resins out-compete recycled resins on price and quality/consistency.

[12] New Plastics Economy. (n.d.). A VISION OF A CIRCULAR ECONOMY FOR PLASTIC.

[13] Technavio. Global Recycled Plastics Market 2016-2020 (IRTNTR8986); 2016. & Technavio. Global Recycled Plastics Market 2018-2022 (IRTNTR21968). Global Recycled Plastics Market 2018-2022 (IRTNTR21968) 2018.

[14] Accuray Group LLP. Global Plastic Recycling Market Analysis & Trends - Industry Forecast to 2025 (AGLP15326208); 2017

4.2 Notable Associations and Actions in Ireland

4.2.1 Polymer Technology Ireland

Polymer Technology Ireland (PTI) represents the plastics and polymer technology industry in Ireland. Membership of PTI includes suppliers of raw materials, services and equipment to the industry as well as the leading polymer processors in Ireland. In 2020, PTI's Ireland 2020 Strategy noted that there are over 230 businesses, employing nearly 7,000 people in the polymer technology industry in Ireland and provides a map of the businesses across the processing and service industries.

4.2.2 CIRCULÉIRE

CIRCULÉIRE [15] is a public-private partnership created by Irish Manufacturing Research and the Department of the Environment, Climate and Communications (DECC), the Environmental Protection Agency (EPA), and EIT Climate-KIC with 25 Founding Industry Members. It is the first cross-sectoral industry-led innovation network dedicated to accelerating the net-zero carbon circular economy in Ireland. Underpinned by systems innovation and utilising a ring-fenced network innovation fund, CIRCULÉIRE will foster innovative collaboration do drive the transition to a zero-carbon circular economy.

4.2.3 Repak

Repak is Ireland's leading environmental not for profit which helps business comply with Irish and EU packaging regulations and supports companies to reduce and recycle packaging waste. Repak have a social mission to lead the recycling and sustainability of Ireland's packaging waste; advocate for a new circular economy; and educate businesses and consumers on reducing and recycling packaging waste. In September 2018, Repak launched their Plastic Packaging Recycling Strategy 2018-2030. It provides a holistic solution to the plastic waste recycling challenges presented by the Circular Economy Package (CEP), which include plastic recycling targets of 50% by 2025 and 55% by 2030[16]. Other Circular Plastics Actions

4.2.4 Training and Research Supports

Several research centres in Ireland are involved in the circular economy and polymer technologies, focused on new and better product development, innovative technologies and solutions and supporting companies in their drive towards sustainability. Examples of the mechanisms used to strengthen research prioritisation are the SFI Research Centres Programme and the EI/IDA Technology Centres Programme

[15] CIRCULÉIRE - The National Platform for Circular Manufacturing in Ireland. (n.d.). Retrieved September 13, 2021, from https://circuleire.ie/

[16] Repak Limited. (2020). Repak Members' Plastic Pledge Report 2020.

4.2.4.1 Relevant centres and supports

Table 3: Relevant Irish Support Centres

Name	Type	Details
APT: Applied Polymer Technology	Technology Gateway	APT is the leading hub for industrial polymer research and development in Ireland, with AIT playing a key role in supporting the Irish polymer and plastics industry for more than 30 years
AMBER: Advanced Materials and Bio Engineering.	SFI Research Centre	Research Areas include: 2D materials and composites, biomaterials, medical devices, semiconductor and memory devices, polymer nanocomposites and membranes.
BIOrbic:	SFI Research Centre	BiOrbic is a national collaboration of over 100+ researchers, focused on the development of a sustainable circular bioeconomy
CREST:	Technology Gateway	The CREST Gateway based in TU Dublin - Kevin St. delivers coatings innovation solutions for industry in the engineering, construction, healthcare and biomedical industries
IBF, Irish Bioeconomy Foundation:		promotes the conversion of Ireland's natural land & sea resources to high-value products for the development of a sustainable bioeconomy that is globally competitive and creates local development.
MET, Medical and Engineering technologies		The Medical and Engineering Technologies (MET) Centre is an interdisciplinary technology centre providing world-class solutions for the Medtech and general manufacturing sectors.
MiCRA, Bio Diagnostics:		MiCRA-Biodiagnostics is an industry-led research & development facility that focuses on the advancement of biosensor technologies, using materials such as enzymes and advanced polymers. MiCRA delivers solutions to companies in many sectors including in vitro diagnostics, environmental, and pharmaceuticals
PEM Gateway:		The PEM Gateway based in IT Sligo has a technology offering for industry in precision engineering, manufacturing and materials targeted at companies based in the North West and nationally
IMR, Irish Manufacturing Research	independent manufacturing and industrial energy efficiency research centre	IMR is a cross-sectoral research centre with partner companies in semiconductors, Information & Communications Technology (ICT), pharmaceuticals, medical devices, food, energy services, aerospace and other areas.
EMD Ireland:	Cluster.	The six gateways that make up the cluster are: Applied Polymer Technologies (APT) at Athlone Institute of Technology (AIT); the Centre for Research in Engineering Surface Technology (CREST) at Dublin Institute of Technology (DIT); South Eastern Applied Materials Research Centre (SEAM) at Waterford Institute of Technology (WIT); Precision Engineering & Manufacturing (PEM) at Institute of Technology Sligo (IT Sligo); Medical & Engineering Technology (MET) at Galway-Mayo Institute of Technology and Design + Gateway at Institute of Technology Carlow
The First Polymer Training Skillnet	SkillNet	First Polymer Training Skillnet is highly regarded by the industry because of the quality of training that it provides, its cost effectiveness and its ability to meet the industry's requirements.

4.3 Technological Developments

4.3.1.1 Irish advances in technology

Revalorisation of Ireland and Europe's resource-rich plastics waste stockpiles is central to the circular plastics economy. The future technologies for plastics circularity are actively being developed by a multitude of global research efforts. Scientifically directed interplay and integration of technologies spanning process, chemical and bioengineering are providing routes to implement nature's regenerative principles for plastics. These technologies focus on the same materials as conventional mechanical recycling but they are still new technologies that have yet to see large-scale implementation.

A growing area of expertise in Ireland is in chemical recycling which may offer some treatment potential for difficult to recycle plastics/polymer streams as a supplement or replacement for mechanical recycling. The challenge lies in whether the industry can develop the technologies to a scale that is both industrially and economically feasible. There is also no EU definition for what is meant by Chemical Recycling. This is something which is under consideration by the Commission.

4.4 Circular Plastics Research and Projects

A number of entities have or are undertaking research in relation to circular plastics and its potential applications in Ireland. In preparing this report, we have engaged with a number of these entities who were happy to discuss the extent of the research they have undertaken, and a summary overview of same is provided in the following.

- BioICEP (AIT): EU-CHINA Flagship H2020 AIT Coordinated Mechano-Green Chemical and Enzymatic Mix-plastic waste degradation and revalorisation as drop in replacement eco-plastics with equivalent performance properties to fossil based polluting plastics. https://www.bioicep.eu/
- PerPETual (AIT): PerPETual is based upon breakthrough proprietary process/technology for the high throughput depolymerization and purification of a broad span of PET material grades into the base monomers, TPA, BHET – bis (2-hydroxyethyl terephthalate) and multimers. Funded through the Irish Government-funded Disruptive Technology Innovation Fund.
- Mix-Up: The Chinese-European MIX-UP is an industry-driven consortium that addresses the market need for novel sustainable routes to valorise plastics waste streams. Funded through Horizon 2020 and the National Natural Science Foundation of China. https://www.mix-up.eu/
- The SFI Plastics Challenge supports interdisciplinary teams to develop innovative solutions that enable the sustainable use of plastics in a circular economy. A number of projects have progressed through a concept Phase Review and are in the project seed Phase:
  1. TURNKEY: Developing an innovative hybrid platform technology to sustainably process food waste and associated contaminated plastic packaging streams.
  2. r²-Epoxy: Targeting the design of novel epoxy polymer networks that combine the well-known and highly sought properties of epoxies, but at the same time are dynamic
  3. PLASMA-LiS: Developing a state-of-the-art, scalable method to convert plastic

waste (water bottles, shopping bags, etc.) into useful, value-added porous carbon materials (PCMs) which will be used as electrodes for advanced lithium-sulfur (Li–S) batteries.

5. Green Lab Services (GLaS): Interrupting lab plastic waste streams by re-evaluating what lab plastic is used for, where it comes from and how it can be reused.
6. Eco-labs: Develop a new eco-solution for lab consumables using biodegradable polymers suitable for landfill.
4. GREEN CLEAN: Decontaminating and upcycling critically contaminated post-consumer plastic waste into usable polymer building blocks which can be then reintroduced into the economy.)

4.4.1 Barriers and Challenges

It is felt, by the Thematic Working Group panel members, that circular plastics can have a strong role to play in a number of different areas that:

- are influenced by government policies and schemes, in terms of greenhouse gas emissions and climate change related policy, waste policy and management,
- have a requirement for a clear mechanism of calculating benefits accruing from recyclate.

Table 4: Specific Irish Challenge Analysis factors

Factor	Title	Description
Economic	Scale	The addressable volume of plastic waste: The quantity generated versus the volume available as feedstock through cost-effective processes and channels
	Trading market.	Long distance from attractive export markets; Relatively small local and regional, markets for recycled products; Limited level of export readiness; Strong competition from imports
	Cost:	The cost of acquiring feedstock, cleaning and processing. Costs: High cost of input material; high compliance costs; high logistics costs; Cost of labour high Costs of transport and/or labour – can either prohibit collection of waste or force a switch to offshore processing
	Infrastructure	Current infrastructure design capacity and potential high capital and operating costs. lack of collection capacity
	Revenue	available markets for the revalorised materials and competitive price points
	Cheap hydrocarbons	what sense does it make for plastic recycling in times of cheap oil and renewable energy sources? How can plastic produced via chemical recycling be competitive against cheap hydrocarbons?
Technological	Tooling	No or limited machine manufacturers; Tooling sector weak.
	Upgrading	The slow pace of technological upgrading physical, mechanical and rheological properties desired
	Better technologies	However, rapidly emerging effective depolymerisation techniques and better product performance characteristics
	Quality Requirements	Traceable inward supply streams with clearly defined segregation between different groups of feed-stocks
	Parameters of recyclate	Melting temperature, Colour distribution and colour composition, Size and form of the granulated material (e.g. lenses, cylinder), Moisture content, Filtration fineness, Ash content, Heavy metal content
Social	Stakeholders	Growing public interest in reducing environmental footprint associated with plastic products. Stakeholders reported a shift in consumer habits to more environmentally friendly practices
	Confusion	Reasonably high uptake in household recycling programs but consumer confusion can result in high contamination rates: Consumers are highly confused which can lead to two things (1) "plastic is always evil" beliefs or (2) complete disengagement with the complicated topic
	Multinational	Multinationals setting ambitious sustainability targets and adopting more circular economy approaches (e.g. Henkel, Coca Cola, Nike, DELL, P&G, Adidas and Target)
Environmental	Health	Increasing volume and long legacy of plastics in the environment leads to ecological, economic and health impacts: Impact of growing microplastics problem - No way to remove and they have ability to move up through the food chain to cause human exposure Impact of toxic additives in plastics – e.g. plasticisers and flame retardants that are potentially released during degradation
	Resources	Depletion of virgin resources - for low value, single-use items
	Land	Increasing waste disposal requirements – landfill sites often stretched beyond capacity, Resulted in increase in domestic burning of waste & exposure to toxic derivatives
Regulation and Policy EU Role		Stakeholders identified the EU as a gold standard for increased regulation driving industry transition to increase both recovery and recycling rates for plastics, although some argue that this creates a slow and overly conservative environment. Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation is assessment of recyclate and 'legacy additives', which has significantly impeded recycling. Recycled plastics cannot be used for food products without the recycling process being authorised by the EU

5 Methodology

The key innovation opportunities identified by the Thematic Working Group:

- Laboratory Lab Waste reprocessed into reusable lab plastic items
- Reusable laboratory waste - Re-using medium bottles- lab / healthcare
- Develop and demonstrate a reusable cup scheme which could be rolled out nationally.
- Fish-Box redesign project- redesign EPS boxes so they can be easily stacked for transport and can fulfil multiple functions.
- Recyclability of meat packaging- Determine levels of EVOH in meat packaging which maintains optimal barrier properties but allows ease of recycling of the packaging post use.
- Cleaning single use bioreactors for reuse
- Collection, decontamination and reuse of PPE
- Processing of thermoset waste with concrete
- Collect and repurpose other fishing related materials- Marine plastic to cleaning bottle plastic

5.1 Thematic Working Group (TWG) Objectives & Scope

The purpose of the Circular Plastics Thematic Working Group (TWG) Synthesis Report is to incorporate the key findings of the State-of-the-Art Review and the 5-10 innovation demonstrator opportunities identified during Ideation Workshops into a public-facing report. Specifically, the aim of this report is as follows: to inform readers of the key policies and regulations (national and EU), drivers and barriers related to developing the circular economy for plastics in Ireland; to map and review international best practices, to take stock of the particular sectoral opportunities/constraints facing CIRCULÉIRE's industry network members, to present 5-10 innovation demonstrator opportunities identified by panel members and developed by the Expert Facilitator, i.e. Athlone Institute of Technology (the authors of this report), which can be funded via CIRCULÉIRE's ring-fenced Innovation Fund (valued between 50K – 250K and with an anticipated timeframe of 12 months).

5.2 TWG Process

The Thematic Working Group brought together 20 panel members from industry and academia and enabled the development of the demonstrator projects through the Thematic Working Group Process as outlined below:

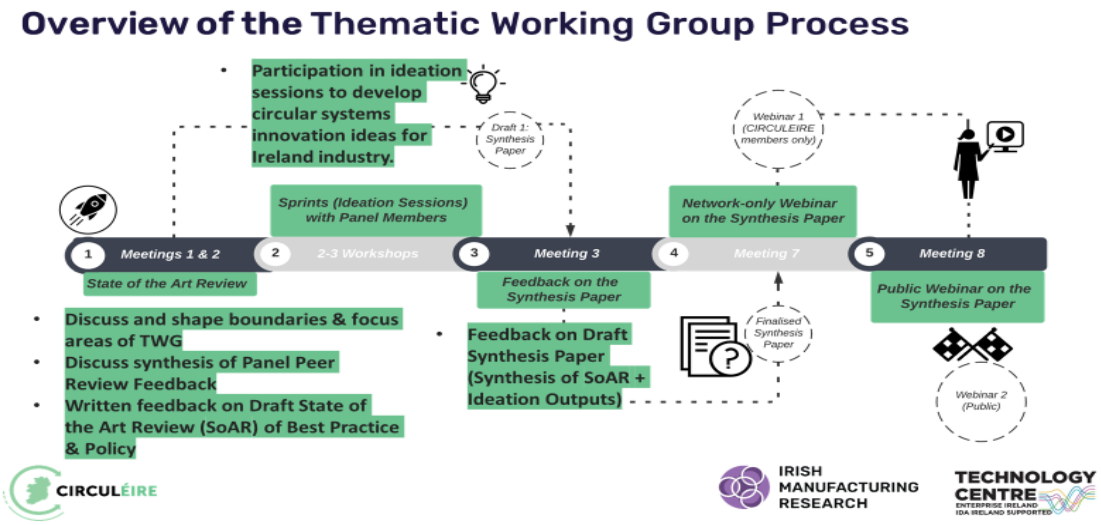

Table 5 offers a high-level summary of nine high-potential Demonstrator projects identified by panel members during the Ideation Workshops, run in July. The projects were developed further through additional feedback from some of panel members, utilising a set of high-level criteria to estimate indicative impacts, potential as a demonstrator project and indicative costs within the context of the CIRCULÉIRE Innovation Fund. Further details about the demonstrator projects are provided in the accompanying CIRCULÉIRE (2021) Circular Plastics Thematic Working Group Synthesis Report.

Table 5: Nine high-potential Demonstrator projects shortlisted through the ideation process

Opportunity	**Main Circular Potential**	**Target Sector**
Laboratory Lab Waste reprocessed into reusable lab plastic items	REUSE	Healthcare/Med Tech
Reusable laboratory waste - Re-using medium bottles- lab / healthcare	REUSE	Lifescience/MedTech
Develop and demonstrate a reusable cup scheme which could be rolled out nationally.	REUSE/Reduce	Service Industry
Fish-Box redesign project- redesign EPS boxes so they can be easily stacked for transport and can fulfil multiple functions.	Redesign	Fishing industry
Recyclability of meat packaging- Determine levels of EVOH in meat packaging which maintains optimal barrier properties but allows ease of recycling of the packaging post use.	REUSE/Recycle	Meat industry
Cleaning single use bioreactors for reuse	REUSE	Lifesciences
Collection, decontamination and reuse of PPE	REUSE	Healthcare/Med Tech
Processing of thermoset waste with concrete	REUSE/RECYCLE	Construction Industry
Collect and repurpose other fishing related materials- Marine plastic to cleaning bottle plastic	REUSE	Fishing Industry

6 Conclusion and Recommendations

Key Messages from Circular Plastics (2021) Thematic Working Group:

- **Ireland needs a clear All-Island Circular Plastics strategy** that examines a future where plastic waste, from whatever stream it comes from, is reduced, revalorised, recaptured and reused.
- **Development of a Circular Plastics Strategy must involve all key players from Ireland's polymers industry**: waste industries, consumer industries, processors and services and set forth a cohesive development strategy for Circular Plastics, not as part of any wider climate, energy, waste or other national policy, but one focused on maximising the utility of our own national plastic waste resources.
- **Focusing on collection, sorting, and recycling alone will not be enough.** Developing infrastructure to collect materials which can be reused and reworked before they become waste will enable the shift of materials higher up the waste hierarchy. These investments in physical infrastructure and technology upgrades are needed to radically improve recycling economics, quality, and uptake.

Developing infrastructure to collect materials which can be reused and reworked before they become waste will enable the shift of materials higher up the waste hierarchy. What is clear from the feedback from the working group panel members is that investments in physical infrastructure and technology upgrades are needed to radically improve recycling economics, quality, and uptake. When it comes to tackling plastic pollution, however, the panel members expressed that a focus on collection, sorting, and recycling alone will not be enough. This view is supported by recent research. According to the July 2020 report developed by The Pew Charitable Trusts and SYSTEMIQ called Breaking the Plastic Wave: A Comprehensive Assessment of Pathways Towards Stopping Ocean Plastic Pollution [17], applying a strategy that focuses solely on recycling—including an ambitious design for recycling coupled with a scaleup of collection, sorting, and recycling infrastructure—would still result in "18 million metric tons [*sic*] of plastic flowing into the ocean each year by 2040".[18]

There is no doubt that plastic is a versatile and widely-used material and that much of the polymer industry is already mobilised in their effort to move away from a use and discard model, investing in product stewardship that is much more focused on sustainability. However, recycling still has the public perception of as being the most impactful solution to the problem of plastic waste. This report advocates that we need to look beyond recycling, to the whole product value chain, to better models of product as service, better designed products, better reusability factors, etc. If we are to accelerate our transition to a low carbon circular economy on a national scale, sufficient funding, supportive frameworks, **substantive industrial buy-in** and infrastructure must underpin national research efforts. Based on the research undertaken related to this TWG, the authors have identified the following nine recommendations aimed at circularising Ireland's plastics sector:

Recommendation 1: Creation of an All-Ireland Circular Plastics Strategy: Ireland needs a clear strategy that examines a future where plastic waste, from whatever stream it comes from, is reduced, revalorised, recaptured and reused. This strategy must involve key actors from the Irish

[17] Ibid.

[18] Ibid.

polymers industry and across the supply and value chain, including: waste industries, consumer industries, processors and services and set forth a cohesive development strategy for Circular Plastics, not as part of any wider climate, energy, waste or other national policy, but one focused on maximising the utility of our own national waste resources. Moreover, given the ubiquity of plastics as a material across virtually every sector in Ireland, and considerably high levels of per capita plastic packaging waste (relative to other EU Member States), the transition to a circularising Ireland's plastics economy will remain difficult unless there is a joined-up and cross-sectoral approach to bringing different parts of the plastics supply and value chain together to agree on actions, objectives and targets together. For this reason, the working group acknowledged that there is a strong basis for establishing a Circular Plastics Sectoral Roadmap as part of the Waste Action Plan for a Circular Economy, with involvement from key stakeholders, including representatives from CIRCULÉIRE.

Recommendation 2: The improvement and expansion of the in-country recycling infrastructure in Ireland will require collaboration between government, research and industry. Due to relatively low volumes of plastics, differences in plastics on the market and contamination (including PVC shrink wrapped labels, glue, paper etc.), it is not currently economical to sort and recycle all different plastics. Potential options here for Ireland arise from

- Producers taking over the recycling parts of the supply chain, to allow the material outputs and inputs to be complementary.
- Digimarc technology [19] to allow improved collection and segregation of packaging for a better-quality recycled material and creation of new recycling streams.
- Provision of financial incentives, such as tax incentives, grants etc. to accelerate the uptake of opportunities.
- Substantial Investment risk in small-scale demonstration projects: many actions at local level would be deemed to be economically unviable at first but with the potential to scale- these projects must be supported

Recommendation 3: The polymer knowledge pool and maturity of the market in Ireland means it is well placed to take advantage of future economic opportunities, however, to inform future strategy and research, a completed market survey of the Irish circular plastics landscape is critical to any future strategy. This report should critically examine:

- The value chain stakeholders and actors
- Global and Irish market demands for recycled polymers current demand and future projections, pricing scenarios and business models.
- Accurate reporting numbers on materials used, methods of recycling, tonnage etc
- A full map of emerging research and processing capabilities
- A comprehensive skills gap analysis
- Full assessment and comparison of the positive and negative aspects of emergent technologies.

Recommendation 4: The data discrepancies discovered during the preparation of this report highlights the disjointed nature of information on policy, legislation, targets and rate numbers. **To**

[19] Accessed online: Digimarc Technology for Protection, Sustainability and Digital Transformation

tackle these data discrepancies, an all -island harmonised data platform should be created – with input from key stakeholders across the plastics value supply chain and waste stream - which captures all the waste value metrics of each of the sub-sectors in plastic. This should align to best practice reporting and where possible, harmonise with other EU systems.

Recommendation 5: Continued research investment into the viability of future technologies which enable a circular plastics economy as well as a better understanding of their overall impacts and outputs. Chemical recycling is seen as a game-changer in the plastics sector [20] and Ireland must make investment to ensure that we are at the leading edge of innovation towards closing the loop in plastics recycling. Related to this point, a clear and common definition of what chemical recycling will be instrumental in making sure that public investments are made in the "right" technologies. The EU Commission are currently working on this to provide clarity to the industry and all stakeholders.

Recommendation 6: Regulation should encourage the production of polymers with improved recyclable qualities that would make it easier to put used plastics back into our economy and invest in cutting the industry's carbon footprint. An examination of should be made of models of regulation (like regulatory sandboxes) that would enable regulators like the FDA to safely test out the safety and performance of circular plastic innovations, such as tightly controlled pilots around introducing recyclates into some production streams, e.g. Class II med device packaging), while also supporting the wider transition to a CE for plastics.

Recommendation 7: Standardise the model used for LCA assessments for Plastics. A 2021 report from the Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) and the Joint Research Centre [21] outlines a structured and comprehensive methodological framework, referred to as the "Plastics LCA method", providing detailed rules to conduct LCA studies of plastic products from different feedstocks, including fossil resources, plastic waste, biomass and CO2 from gaseous effluents. It is hoped that this methodology will become the standard framework across Member States and the private sector to assess, display and benchmark the environmental performance of products or services based on a comprehensive assessment of environmental impacts over the product life cycle, according with one of the core objectives of the Roadmap to a Resource Efficient Europe [22] . Support must be given by the Government to allow for the dissemination of this methodology to technical experts to enable the establishment of consistent and reproducible LCA studies that effectively optimise design for recyclability and support environmental management along the value chain.

Recommendation 8: Support Retailers and Brands to develop circular plastics pilots: Developing and implementing sustainable product strategies for brands and retailers specifically in Ireland and running pilots with brands and retailers to develop products with

[20] ACS Sustainable Chem. Eng. 2021, 9, 36, 12167–12184, Publication Date:August 9, 2021, https://doi.org/10.1021/acssuschemeng.1c03587

[21] Nessi, S., Sinkko, T., Bulgheroni, C., Garcia-Gutierrez, P., Giuntoli, J., Konti, A., Sanye Mengual, E., Tonini, D., Pant, R., Marelli, L. and Ardente, F., Life Cycle Assessment (LCA) of alternative feedstocks for plastics production, EUR 30725 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-38144-0, doi:10.2760/693062, JRC125046.https://publications.jrc.ec.europa.eu/repository/handle/JRC125046

[22] EC (2011): COM(2011) 571 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Roadmap to a Resource Efficient Europe

recycled post-consumer and post-industrial plastic waste.

Recommendation 9: Inspire designers: Provide the knowledge, tools and inspiration to empower designers, technologists, and product developers to design more sustainable, longer lasting products, building circularity into design training at all levels. Also important is the training and upskilling of the workforce through the integration of circularity into education and training programmes and engagement between government and enterprise to enable access to these programmes, good quality jobs, and an inclusive labour market that provides opportunities for people that are distant from or at risk of being phased out of the labour market. These measures could be delivered through a number of schemes such as Apprenticeships, Skillnet, FETAC and other private social and economic training providers.

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