Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS – FOR PUBLICATION

Project Title	Agri Bio Circular Economy (*ABC Economy*)
Lead Grantee (Organisation)	University College Dublin
Lead Grantee (Name)	Dr Fionnuala Murphy
Final Report Prepared By	Dr Fionnuala Murphy
Report Submission Date	

	Name	**Organisation**
Project Partner(s)	Percy Foster, Tony Breton	Cré - Composting and Anaerobic Digestion Association of Ireland
Collaborators	Paul Clifford Anthony Fitzgerald	Monaghan County Council Tipperary County Council

Project Summary (max 500 words)

ABC Economy developed new sustainable value chains for the circular bioeconomy in Ireland by maximising value and minimising environmental impacts through cascading of biomass for production of biobased products and energy. *ABC Economy engaged with key stakeholders through project partner, Cre, and project collaborators, Tipperary County Council and Monaghan County Council, to develop sustainable value chains based on the bioresources available in each region. ABC Economy characterised available biomass and assessed the potential of valorisation processes for bioproduct and energy production in a circular economy context. Key stakeholders (primary producer, processors, waste management companies etc.) were engaged to identify important resources, constraints to valorisation, and potential opportunities. Central to ABC Economy is the full supply chain sustainability analysis to examine synergies and trade-offs between using biomass for energy generation and biobased products and to minimise trade-offs by considering the impacts of circular economy principles and* *cascading. ABC Economy value chains were developed in line with key stakeholders to ensure the viability and potential uptake of these novel value chains.*

Upon reflection and further discussion with stakeholders, the final ABC Economy Value Chains were developed. A simplified system was preferred as, if one technology is not operational, then the whole system cannot function, causing a backlog in feedstock, which would require storage at cost. Also, more emphasis was placed upon biogas as an output product as this was a clear favourite as voted by our stakeholders. Pyrolysis and anaerobic digestion are well established technologies elsewhere in Europe, they are relatively easy to operate, and the CAPEX and OPEX are reasonable compared to other technologies. Hydrothermal Carbonisation is a promising technology for the processing of 'wet' feedstocks. These technologies can be placed in a cascade in either order depending on location or product most desired.

ABC Economy research has shown, where biomass wastes are already being used in an environmentally, economically, and socially sustainable manner, this system should not be tampered with, rather enhanced by finding valorisation options for the remaining residues. Cascading systems of technology use are encouraged to realise the full value of biomass wastes, while minimising environmental impacts. It is important to focus on products which are in demand in Ireland, filling a market requirement and ensuring the profitability of cascading technology system. Creating indigenous fertiliser and energy sources are important for the island of Ireland, not only in meeting market demand, but also in helping reduce GHG emissions and thereby achieving carbon reduction targets.

A key output of ABC Economy is the Developing the Bioeconomy – Guide for Local & Regional Authorities. This guide was created to help demystify the bioeconomy for local and regional authorities based on the ABC Economy project experience. The area of bioeconomy can be quite large and intimidating for new actors to decide where best to place their efforts to develop bioeconomy or how/who to link in with. This guide seven-step has considered the findings from the biomass analysis, stakeholder workshops, and cascading technology reviews conducted in ABC Economy. The full booklet and infographic can be found at www.abceconomy.ie/publications.

Keywords (min 3 and max 10)	Bioeconomy, sustainable value chains, waste valorisation, bioenergy, biomass, life cycle assessment, stakeholder engagement,

NB – Both Section 1 and Section 2 of this Final Report will be made publicly available in a Final Technical Report uploaded online to the National Energy Research Database.

In the following Section, please provide a clear overview of your project, including details of the key findings, outcomes and recommendations. The section headings below are provided as a guide, please update or add to these as best suits your project.

By submitting this project report to SEAI, you confirm you are happy for Section 1 and Section 2 of this report to be made publicly available. If you wish to request edits to this section in advance of publication, please contact SEAI at EnergyResearch@seai.ie.

SECTION 2: FINAL TECHNICAL REPORT – FOR PUBLICATION (max 10 pages)

2.1 Executive Summary

ABC Economy developed new sustainable value chains for the circular bioeconomy in Ireland by maximising value and minimising environmental impacts through cascading of biomass for production of biobased products and energy. ABC Economy engaged with key stakeholders through project partner, Cre, and project collaborators, Tipperary County Council and Monaghan County Council, to develop sustainable value chains based on the bioresources available in each region. ABC Economy characterised available biomass and assessed the potential of valorisation processes for bioproduct and energy production in a circular economy context. Key stakeholders (primary producer, processors, waste management companies etc.) were engaged to identify important resources, constraints to valorisation, and potential opportunities. Central to ABC Economy is the full supply chain sustainability analysis to examine synergies and trade-offs between using biomass for energy generation and biobased products and to minimise trade-offs by considering the impacts of circular economy principles and cascading. ABC Economy value chains were developed in line with key stakeholders to ensure the viability and potential uptake of these novel value chains.

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2.2 Introduction to Project

Agriculture is Ireland's largest indigenous sector and accounts for 7.1% of total employment with total agri-food exports amounting to approximately €15.2B in 2021 (Bord Bia, 2021). However, agriculture is also a significant contributor to greenhouse gas (GHG) emissions accounting for 37.4% of Ireland's total GHG emissions (including fuel consumption for agriculture & forestry) in 2020. These GHG emissions are projected to increase to 43.4% by 2030 if no additional mitigation measures are adopted (EPA, 2022). In 2016, emissions from agriculture rose by 2.7% - largely due to expansion in the dairy sector caused by an abolition of milk quotas (EPA 2018, Joint Committee on Agriculture, Food & the Marine 2018). To reach Ireland's new target of 51% GHG emission reduction by 2030 significant measures will need to be implemented in the agricultural and forestry sectors (EPA, 2022).

As many biological waste (or co-product) streams from the agri-food sector are rich in biochemicals, they have significant potential for biorefining, thereby maximising the potential value and impact of biomass use by processing it into a cascade of products, from high added value chemicals to low added value energy.

There are approximately 130,000 individual farms in Ireland, with 66% of the land footprint dedicated to agricultural use (Central Statistics Office, 2020). According to Bord Bia (2019), the Irish beef market will grow due to increased demand for beef with high quality assurance and sustainability standards. Poultry is the fastest growing sector in this area and pork is the most widely consumed meat in the world (FAO, 2009). With this intensification of meat production comes a challenge in managing animal by-products, manure, and GHG emissions.

Ireland is a leader in crop production, with the world's highest average wheat yields and the second highest barley yields (Teagasc, 2016). Barley and wheat straw are primarily used for animal feed, and this demand is likely to increase due to growth in the dairy and livestock sectors (Teagasc, 2016). Oats are a traditional Irish crop grown to feed horses, but now mainly to feed people and sport horses - demand for oats will increase by at least 50% over the next eight years (Teagasc, 2016). However, expanded crop growth leads to increased GHG emissions from fertiliser production and the breakdown of fertiliser in soils (Teagasc, 2016).

Forestry cover in Ireland is estimated to be at its highest level in 350 years with 11% coverage and is expected to more than double by 2035 (Department of Agriculture, Food and the Marine, 2019; Government of Ireland, 2018). However, a large amount of waste arises at forest sites and sawmills – mostly tree branches and tops, saw dust, off-cuts, and shavings. These biomass resources could all be diverted to energy production using appropriate technologies.

Developing renewable energy sources is a key national objective towards reducing GHG emissions. However, there are competing demands on biomass for food, feed, functional material, and fuel. The National Policy Statement on the Bioeconomy of Ireland suggests a cascading principle of biomass use, where higher value applications are derived from bioresources before they are used for energy generation (Government of Ireland, 2018). Biomass can be defined as 'the biodegradable fraction of products, waste, and residues from agriculture (including vegetal and animal substances), forestry and related industries…' (Vis, et al., 2010). Agricultural wastes have the highest potential for biorefining, but the access to these materials is a key issue (Ricardo Energy & Environment for Zero Waste Scotland, 2017). A systems change involving data collection at individual farms and developing new value chains will play a pivotal role in ensuring the overall sustainability of Ireland's increasingly intensified agricultural and forestry sectors (Teagasc, 2016).

To address these issues, the Agri Bio Circular (ABC) Economy project was established under the Sustainable Energy Authority Ireland (SEAI) Research Development & Demonstration Call 2018 Co-Funded by the Department of Agriculture, Food & the Marine (DAFM) - An investigation to quantify the impact of applying circular economy. The aim of the ABC Economy project is to develop sustainable value chains which will enhance the development of biomass-to-energy and biomass-to-bioproduct pathways in Ireland through a cascading use of resources. The focus was on case studies on Monaghan and Tipperary County Councils (Figure 1). This project was undertaken with the support of project partner Cré – Composting and Anaerobic Digestion Association of Ireland.

Figure 1: Map of Ireland with Counties Monaghan and Tipperary Highlighted

2.3 Project Objectives

The aim of *ABC Economy* was to develop new sustainable value chains for the circular bioeconomy in Ireland by maximising value and minimising environmental impacts through cascading of biomass for production of biobased products and energy.

The ABC Economy project had five key objectives to achieve this aim;

1. To link with Local Authorities and key stakeholders to quantify and characterise the regional biomass resource base,
2. To link with key actors and stakeholders to map existing value chains and identify potential routes for circularity in the reginal bioeconomy,
3. To assess technical and market potential of valorisation processes and identify competition between biomass for energy/fuels and biomass for bio-based materials/chemicals,
4. To assess the impacts of new biomass value chains holistic life cycle analysis to achieve systems-level efficiency and minimise trade-offs between competing uses in the bioeconomy,
5. To effectively disseminate project results to maximise the impacts of ABC Economy in accelerating the transition to a biobased circular economy in Ireland and raise the profile of the bioeconomy among primary producers and the public.

2.4 Summary of Key Findings/Outcomes

Describe how your project has furthered the current state-of-the-art, current knowledge or current practice. Clearly highlight the degree of novelty and innovation demonstrated by your project.

Address each innovation in a bullet point below. Add as many bullet points as you need:

- *Innovation 1: Regional Biomass Quantification*
- *A resource approach was followed to assess the biomass availability in each region. This approach focuses on the resource base and the competition between different uses of the resources. Manure/litter from livestock and poultry is the most significant contributor to biomass available in each county under due to the high amounts of livestock and poultry in each county and their relative manure production. Crop biomass (straw and mushroom) is the next most significant amount of biomass available for valorisation. Spent mushroom compost and mushroom offcuts make up the bulk of biomass available in Monaghan due to the large focus on mushroom growing here. There is a low amount of forestry biomass available in each county.*
- *Innovation 2: Stakeholder Engagement*
- *The first in a series of workshops was held with stakeholders in Monaghan and Tipperary to understand the opportunities and barriers to valorising wastes, and to inform the development of new value chains. Workshops discussions were separated into four main themes - Market, Feedstocks, Logistics, and Knowledge/Communication - with each stakeholder having an opportunity to discuss each theme. There were several recurring topics discussed within these themes from both a positive (opportunity) and negative (barriers) viewpoint by the workshop delegates; Communication to Link Actors, Dissemination of Knowledge, Local / Rural Ireland Development & Cooperation, Legislation & Regulation, Incentives / Funding, Cost, Perception*

of Waste, and Characteristics & Separation of Feedstocks. These opinions were utilised when reviewing technology options and developing cascading technology systems. In general, there was an appetite for valorising biowastes occurring onsite, but the overarching barriers were related to markets. Stakeholders want to ensure there is a well-developed market for their products before pursuing this pathway. This concern about markets and supply/demand is reflected in the content of workshop #2.

- *Workshop #2 "Potential New Technologies in the Bioeconomy" had the overall aim to present project progress and proposed technology chains to project stakeholders gather feedback on the proposed technology chains. A variety of cascading technology options were developed with their outputs products primarily focused on fertiliser and energy/fuel production. Each cascading technology option has benefits and drawbacks, including expense, feedstock requirements, and market demand. Two separate technology value chains were presented to stakeholders, one relating to manures / poultry litter and the other relating to forestry / crop residues). A series of poll questions were put to our audience covering technological feasibility, market demand, and consumer acceptance. As this is a stakeholder focused project feedback on these technology chains was used to develop the final ABC Economy Value Chains.*

- *Innovation 3: Value Chain Development*
- *Twenty-one individual technologies were reviewed for their suitability to process biomass available and potential to operate in together in a cascading system. There are a wide range of technologies available to treat biomass, they largely fall into four categories: biochemical, biological, physical, and thermochemical. Some technologies have been ruled out from consideration in this project based on an initial analysis due to factors including high OPEX and/or CAPEX, environmentally unsustainable, or unsuitable for biomass available in ABC Economy.*
- *Following a full review of these technologies, cascading systems of technology use were investigated. Some technologies lend themselves well to cascading systems (e.g., AD, precipitation), whereas others cannot be appropriately slotted into a cascading system (e.g., hydrothermal treatments).*
- *Two separate technology value chains were presented to stakeholders, one relating to manures / poultry litter and the other relating to forestry / crop residues / SMC. Upon reflection and further discussion with stakeholders, the selected ABC Economy Value Chains were developed.*
- *Innovation 4: Sustainability Assessment*
- *Case studies have been carried out on the life cycle assessment and economic analysis of new valorisation systems in each region. The analysis included evaluation of existing systems/products which will be affected by market uptake of the valorisation systems considered in ABC Economy; allowing for quantification of the environmental benefits/trade-offs arising from the avoided use of these systems/products.*

2.5 Project Impact

Clearly position the impact of your project with reference to the needs of the Irish Energy Sector, national and international policy objectives, and SEAI's remit.

Discuss the key impacts of your project: societal, economic, technological or otherwise. Clearly identify and highlight the value of your project in the wider context.

The ABC Economy carried our regional case studies, assessing the environmental and economic impacts of agri-food waste valorisation. Each of these case studies considered the impact of the relevant valorisation technology on the wider environment.

- *Case Study 1: Life Cycle Assessment of Anaerobic Digestion of Poultry Litter in Monaghan*
    - *In this case study, consequential life cycle assessment (CLCA) was conducted to examine several scenarios where biogas produced from poultry litter in Country Monaghan is used to generate heat and electricity or is upgraded to biomethane which can substitute natural gas. For all of the scenarios considered in this study, diverting poultry litter to AD leads to reduced environmental impacts for global warming, fine particulate matter formation and terrestrial acidification. However, the extent to which environmental impacts are reduced varies significantly across the scenarios. Displaced processes including electricity or natural gas, peat moss production and avoided land spreading of litter contribute the most to reducing environmental impacts. CLCA is a suitable tool to inform decision-makers about the impact of introducing a new multifunctional technology like AD when considering the systems which are displaced. The results show the range of potential environmental outcomes, rather than predicting a single most-likely outcome. The results of this study indicate that AD is a suitable disposal route for poultry litter which may lead to reduced environmental impacts. This type of analysis is recommended when considering alternative feedstocks and valorisation pathways in the circular economy. This research is published with open access; Beausang, C., McDonnell, K. & Murphy, F. 2020. Anaerobic digestion of poultry litter – A consequential life cycle assessment. Science of The Total Environment, 735, 139494, doi: 10.1016/j.scitotenv.2020.139494.*

- *Case Study 2: Life Cycle Assessment of Anaerobic Digestion of Manure and Grass Silage in Tipperary*
    - *In this study, CLCA was conducted to examine mono-digestion of cattle slurry and co-digestion with grass silage in different ratios on a VS basis in County Tipperary. The prior uses of the feedstocks were considered, along with the processes displaced by the biogas and digestate produced. The net environmental impact varied according to the proportion of silage and slurry digested. Higher environmental burdens were observed for mixes with a greater ratio of grass silage to slurry. The optimum environmental performance for the baseline scenario was observed at a VS ratio of 0.4:0.6 for silage and slurry, where there is a net reduction for all impact categories considered. The choice of marginal technologies that are displaced has a significant influence on the results, as have the assumptions about how the grass silage is sourced. This study provides greater insight into the environmental impacts of co-digesting an energy crop with animal manure in varying proportions. This research is published with open access; Beausang, C., McDonnell, K. & Murphy, F. 2021. Assessing the environmental sustainability of grass silage and cattle slurry for biogas production. Journal of Cleaner Production, 298, 126838, doi: 10.1016/j.jclepro.2021.126838.*

- *Case Study 3: Life Cycle Assessment of Anaerobic Digestion of Spent Mushroom Compost in Monaghan*
    - *Implementation of anaerobic digestion as an alternative on-site technology to reduce dependency on grid-based electricity was assessed in a case study on mushroom production in Co. Monaghan. Spent mushroom substrate (SMS) is becoming available in increasing quantities posing a great environmental challenge in terms of its effective disposal. Valorisation practices are aimed at utilising waste and changing its constituent parts through physical and chemical changes to a value-based product. Life cycle assessment was used to estimate the environmental impact of valorisation processes on the performance of the mushroom supply chain Global Warming Potential was estimated for mushroom production at 2.84 CO_{2eq}/ kg mushroom with anaerobic digestion reducing emissions by 0.16 CO_{2eq} per kg of SMS processed. Thus, AD is an alternative way to treat SMS. The results from the LCA study provided an example of how an on-site valorisation process can help reduce environmental burden from mushroom production.*

- *Case Study 4: Techno Economic Assessment of Anaerobic Digestion of Manure and Grass Silage in Tipperary*
    - *Assessment of the economic viability and profitability of AD of grass silage and cow manure was carried out in a case study for Country Tipperary. In the study, biogas was upgraded to biomethane and subsequently injected into the national gas grid. A net present value (NPV) formula was used to calculate profits, thus converting total profits over the lifetime of the facility into present-day values. The results show that NPV of AD facilities increases as the incentive level for biomethane increases, with NPV remaining positive for all scenarios when the biomethane incentive level was 100 €/MWh, with the maximum NPV yielding €42 million for the theoretical facility in Thurles. At the biomethane incentive level of 60 €/MWh, feedstock costs were the critical factor in determining profitability, with NPV only remaining positive when the total feedstock cost (TFC) was 19 €/t. NPV was negative in all scenarios when TFC was 47 €/t, and was negative in all but one scenario when TFC was 33 €/t. A comparison of VSRs showed that NPV increases as the VSR of grass silage to cattle slurry increases due to larger biomethane production at a VSR of 6:1 than 4:1, resulting in the highest NPV being 33% greater for VSR of 6:1 than 4:1, generating an NPV of €28 million versus €21 million (incentive level of 100 €/MWh, TFC of 19 €/t), and the lowest NPV for VSR of 4:1 (€ -4.2 million) being double that of the lowest NPV (€ -2.1 million) for VSR of 6:1 (incentive level of 60 €/MWh, TFC of 47 €/t). This study highlights that current grass silage feedstock levels are a key limiting factor to AD viability in the county, with TFC being a limiting factor at the lower biomethane incentive level of 60 €/MWh. The calculations here show that AD of grass silage and cow slurry in Tipperary can be economically viable and highly profitable, especially at the higher biomethane incentive level of 100€/MWh. This research is published with open access; Padi, R. K., Douglas, S. & Murphy, F. 2023. Techno-economic potentials of integrating decentralised biomethane production systems into existing natural gas grids. Energy, 283, 128542, doi: 10.1016/j.energy.2023.128542.*

- *Case Study 5: Value Chain Pyrolysis + Anaerobic Digestion (AD)*
    - *This study evaluates the integration of pyrolysis with AD for effective utilization of biochar in digestion of poultry litter for production of bioelectricity and upgraded biomethane from biogas. The use of biochar in high solids anaerobic digestors processing chicken litter substantially improves the biomethane production especially at 1:1 total solid (TS) dosage of wood biochar and feed. However, the biomethane yield varies at different loading TS. Based on the loading TS with biochar (i.e., 28%, 15% and 8%) and two final energy products (bioelectricity and upgraded biomethane), the six scenarios were developed to assess the energy demand and environmental impacts of whole value chain. The scenarios with biomethane upgradation which is assumed to displace natural gas in national grid demonstrated the higher energy savings and reduced environmental impacts than scenarios with bioelectricity as final output. The processes that are displaced such as avoided electricity production and avoided peat moss production have the largest negative values for bioelectricity scenario, whereas avoided natural gas production and peat moss combined demonstrated larger negative values in biomethane scenarios. The results also showed that biomethane upgrading has substantial CO_2 savings and lower fossil depletion potential than bioelectricity production from biogas owing to the avoided natural gas production. However, reduced eutrophication potential (EP) was evidenced in bioelectricity scenarios than biomethane ones, as reduced EP was associated with the displaced electricity production process. This study concludes that integration of pyrolysis and AD facilities in substantial environmental benefits and maximizes the scope for the development of new sustainable value chains in Ireland. This research has been published (Energies 2024, 17(7), 1511; https://doi.org/10.3390/en17071511).*

- *Case Study 6: Value Chain Anaerobic Digestion + Hydrothermal Carbonisation (HTC)*
    - *This study examines the combination of processes i.e., slurry/grass digestion at AD facility followed by digestate valorisation through HTC. Scenarios including mono-digestion (only slurry), co-digestion (grass:slurry), bioelectricity production and biomethane upgrading were evaluated. The environmental impacts varied across the*

scenarios depending on digestion type and displaced processes considered such as electricity and natural gas production. The monodigestion of slurry demonstrated higher environmental savings than co-digestion, where with increase in silage proportion in feedstock digestion mix indicated reduction in emissions savings (upstream feedstock production included). Moreover, in scenarios where upgraded biomethane was assumed to substitute heating by natural gas indicated improved environmental profile (esp. CO_2 emissions) than scenarios which assumed displacing electricity grid by bioelectricity. The impact categories, eutrophication potential and fossil depletion were mainly influenced by the avoided coal production (substitute of hydrochar pellets) and avoided electricity production, whereas acidification potential and particulate matter formation was influenced by avoided manure storage and application. This study concludes that application of AD in combination with HTC would facilitate in more bioenergy production, however, optimizing the energy use in HTC and use of greener sources would potentially further improve the environmental performance of the whole value chain. This research has been submitted for publication.

2.6 Recommendations

Please highlight any implications/opportunities/recommendations for Ireland (e.g., for policy makers, for the research community, for industry) based on the work carried out in the project.

A key output of ABC Economy is the Developing the Bioeconomy – Guide for Local & Regional Authorities (also known as the Bioeconomy Innovation Blueprint). This guide was created to help demystify the bioeconomy for local and regional authorities based on the ABC Economy project experience. The area of bioeconomy can be quite large and intimidating for new actors to decide where best to place their efforts to develop bioeconomy or how/who to link in with. This seven-step guide aims to assist with this and point new and existing stakeholders in the right direction. This guide has considered the findings from the biomass analysis, stakeholder workshops, and cascading technology reviews conducted in ABC Economy. The full booklet and infographic can be found at www.abceconomy.ie/publications.

1. *DETERMINE BIOMASS QUANTITIES & CHARACTERISTICS*

Gather data on biomass. What is available? Is pre-treatment required? Consider storage and transport too.

2. *IDENTIFY TECHNOLOGIES & DEVELOP BUSINESS MODELS*

Cascading technologies unlocks the full potential of biomass and offers new business models which derive optimum value from bioresources storage and transport too.

3. *CONDUCT FEASIBILITY, MARKET & POLICY ANALYSES*

The most important aspect to developing a successful bioeconomy initiative is to ensure economic, social, and environmental sustainability.

4. *ENGAGE LOCAL STAKEHOLDERS*

Ensure integration with Local Economic & Community Plans, Regional Enterprise Plans, & County Development Plans; industry perspective is crucial to achieving commercial success.

5. *FOSTER INNOVATION SPRINTS*

Innovation sprints fostering initial collaborations between industry, local further & higher education institutions, and Innovation clusters can help jump-start bioeconomy projects.

6. *CREATE KNOWLEDGE NETWORKS*

Strong knowledge and communication networks help stakeholders identify collaborators and opportunities, nurture ideas, and ensure integration of science, technology, and innovation.

7. *DEVELOP AWARENESS & COMPETENCIES*

Develop awareness & competencies within the local authority. Information on the bioeconomy should be communicated at targeted organisations.

2.7 Conclusions and Next Steps

ABC Economy has shown there is a significant quantity of biomass resources which can be gathered for valorisation without obstructing current uses, in a regional context. ABC Economy has shown, where biomass wastes are already being used in an environmentally, economically, and socially sustainable manner, this system should not be tampered with, rather enhanced by finding valorisation options for the remaining residues. Cascading systems of technology use are encouraged to realise the full value of biomass wastes, while minimising environmental impacts. It is important to focus on products which are in demand in Ireland, filling a market requirement and ensuring the profitability of cascading technology system. Creating indigenous fertiliser and energy sources are important for the island of Ireland, not only in meeting market demand, but also in helping reduce GHG emissions and thereby achieving carbon reduction target.