Sustainable
Cork
Programme

ANAEROBIC DIGESTION

A Circular Solution for Energy Resilience

Contents

Foreword

Cork Chamber represents 1,200 members employing over 100,000 people and our vision is for Cork to be the best place for business, empowered by a thriving, diverse and influential membership. We are committed to the United Nations Sustainable Development Goals, which guide and influence our activity.

In April 2020 we initiated the Sustainable Cork Programme at the height of the COVID 19 pandemic, a hugely challenging time for businesses, and society. The programme is designed to set a vision for a more sustainable and resilient Cork, and explores the sectoral challenges and the opportunities for a sustainable, strong recovery, in parallel with a discussion of the vision for Cork.

Our cornerstone Sustainable Cork programme report, Building Economic Resilience, sets out the views of almost 1,000 businesses and citizens, prioritising climate action, connected public transport, quality of life, affordable accommodation, and the opportunities for a Living City region, painting a picture of the Cork that people want to live in, work in and enjoy.

Simultaneously, we undertook an incredible partnership with the UCC Centre for Cooperative Studies, driven by Noreen Byrne and Dr Carol Power. Ashley Amato a final year MSc Co-operatives, Agri-Food and Sustainable Development student joined us to define the issues around bringing anaerobic digestion to bear in a meaningful way to help make Ireland carbon neutral.

Ashley, took the helm of a group of enthusiastic industry leaders and stakeholders to present, in this report, the opportunities that can be enabled by real commitment to delivering anaerobic digestion at a scale.

With anaerobic digestion we can make a deep impact on the sustainability of the energy that we consume, and the wasted resources that currently exist in agriculture, wastewater treatment and food production.

We can take a step closer to being a truly circular economy, and to living the vision of a leading, green, open, island economy.

I sincerely thank Ashley and the team at the UCC Centre for Cooperative Studies, and the industry experts and stakeholders who have guided the content and recommendations set out in this report.

I am proud to bring this report to our members, stakeholders and Government and ask that the recommendations set out and the potential for our economy is carefully considered by all.

Thomas Mc Hugh
Director of Public Affairs
Cork Chamber

Executive Summary

Climate action will define the economic resilience of Ireland in the years and decades to come. There is an urgent need for Ireland to transition to a sustainable, resilient, and carbon neutral society. The generation of biogas and biomethane (renewable gas) through the process of anaerobic digestion (AD) is a critical component in decarbonising energy, agriculture, transport and heat and ensuring the nation's energy security. A projected rise of the country's population to 6.7 million by 2051 along with increased economic activity and energy demands is pushing the sustainability agenda forward[1].

As the country is not on track to meet any of its renewable energy and greenhouse gas (GHG) targets greater attention and support for large-scale commercial and on-farm AD is needed. Gas Networks Ireland is currently preparing to deliver up to 37% of renewable gas through the gas network by 2050, in order to decarbonise it along with heat, transport and agriculture[2]. The development of AD and renewable gas production across Ireland has the potential to save over 2.6m tonnes of CO2 emissions per annum and reduce GHG emissions from agriculture from 35% to 48%[3,4]. Anaerobic digestion provides a continuity of generation that other renewables cannot and must be an integral part of our energy blend as we move past fossil fuel reliance. This urgency and the significant role that renewables will play in enhancing the region's attractiveness and green credentials has been recognised by the Cork business community in the Sustainable Cork Programme, Building Economic Resilience Report[5].

This report is part of the Sustainable Cork Programme which is guided by Cork Chambers commitment to the UN Sustainable Development Goals. It has been developed in partnership with University College Cork's Centre for Cooperative Studies. It provides an exploration of the wide-scale commercial development of AD via the co-operative model. It identifies the policy and planning improvements required to realise its full potential. It seeks to elevate awareness of the potential of anaerobic digestion among business and political leaders and to identify measures that could accelerate the development of this renewable infrastructure at a time of climate crisis.

In Ireland anaerobic digestion is already proven in many operational facilities. There is a great flexibility to the technology that can adapt to different feedstocks and blends, turning waste into energy and capital. In many ways it is the purest representation of what the circular bioeconomy has to offer. The technology has been embedded at significant levels in multiple countries that have a supportive regulatory and fiscal environment.

With a strong cooperative network and ethos in Ireland, and a planning and regulatory system that needs refinement rather than revolution, we are well placed, if not ideally and uniquely placed to capitalise on the potential of anaerobic digestion to provide a stable baseload of green energy. The focus now must be on ensuring that the fiscal environment is encouraging, through increased focus within the Renewable Electricity Support Scheme and by actively signalling intent to the market. As in every facet of energy generation, when the investor environment is facilitative, the market responds quickly. The RESS programme is nothing but positive, but it must support a diversity of technologies to truly ensure energy resilience that is green, sustainable and robust.

Methodology

The methodology for the report was guided by Cork Chamber, the Centre for Cooperative Studies, and the expert stakeholder group based on commercial and policy considerations. Following a review of the literature, relevant Irish policy, and international case studies, two expert stakeholder discussion groups, and a number of in-depth one-to-one meetings were held to examine the following:

- What is the opportunity for biogas production?
- Which are the most sustainable and feasible feedstocks?
- What are the barriers to developing Cork's biogas market?
- Can the cooperative model accelerate the potential of the industry? If not, what model can?
- What are the levers that can activate this potential?
- What can government do?

What is the Bioeconomy?

The bioeconomy, or *"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"*[6], is based on principles of sustainability and circularity. In order to take meaningful climate action, the bioeconomy must be at the heart of Irish policy. Anaerobic Digestion is one part of the bioeconomy and one part of the solution to some of the socio-economic and environmental issues in Ireland.

What is Anaerobic Digestion?

The process of anaerobic digestion is an integral part of the bioeconomy. It is a flexible technology that breaks down organic matter or feedstocks in an oxygen-free environment to generate a renewable energy source, biogas[7]. Feedstock is essentially the fuel for anaerobic digestion. It can be a wide range of materials from agricultural slurry, to sewage sludge, food waste, agricultural residues or grass. Biogas can be upgraded to biomethane (renewable gas), which can be injected directly into the grid or used as a transport fuel, replacing natural gas and other fossil fuels. AD also produces a valuable by-product, digestate, a nutrient rich organic fertilizer, thereby reducing the need for inorganic fertilizer use comprised of non-renewable resources[8]. The development of Ireland's AD sector is critical to developing our bioeconomy and effectively transitioning our nation into a global circular economy leader.

How do we compare with other countries?

The widespread development of the bioeconomy and AD within the European Union and internationally has been ongoing for years. Countries including Sweden, Germany and the UK are far ahead of Ireland in these sectors, resulting in vast social, economic and environmental benefits. The gravity of being a leader in today's highly competitive global economy demands that we act now, lest we risk falling further behind.

Does Irish Policy Support Anaerobic Digestion?

Current Irish policy support for AD development is limited. While the new Programme for Government, "Our Shared Future", recognises the urgent need to mitigate climate change, it lacks detail on the development of Ireland's AD sector. The supreme court has ruled that a more ambitious climate action plan specifying how 2050 targets will be met is urgently required[9]. Within this, a supportive AD plan must be developed.

The Renewable Electricity Support Scheme (RESS) is the country's most recent and significant support scheme for renewable energy generation, aiming to help Ireland meet its carbon and renewable energy 2030 targets. The competitive auction cost-effective framework favours solar and wind energy, both intermittent non-dispatchable sources[10]. With the results of the first auction revealing that only solar and onshore wind applications were successful in receiving government support[11], greater attention and understanding of the vast benefits of AD and bioenergy production is required.

What is Ireland's AD Potential?

Ireland has the highest potential for biomethane production per capita in the EU[12]. This potential, however, has been left largely untapped due to challenges relating to financial viability, certainty over feedstock supply, lack of infrastructure, policy, regulatory and legislative environments, market immaturity, and behavioural challenges. Mobilising this potential and developing the necessary infrastructure will boost the country's green credentials and enhance the regions attractiveness to foreign direct investment (FDI), potentially generating €1.5 billion in direct investment and 3,600 new permanent jobs[13], while reducing the nation's agricultural industry's GHG emissions by 35-48%[14]. This agenda is further being driven forward by the Cork business community, as noted in the Sustainable Cork Programme.

Ireland's substantial Agri-Food industry is a pivotal economic driver but also accounts for 33% of overall GHG emissions[15]. AD is an obvious solution to enhance the industry's sustainability, while decarbonising industrial heat and transport. The immense value of creating better and more sustainable organic fertilizers in the form of digestate further illuminates the potential awaiting the nation in transitioning to a circular bioeconomy. By utilising and capitalising on currently under-utilised and oftentimes wasted resources, the country can make its mark globally as a leader in the bioeconomy.

The co-operative model, which has remained an integral component of the Irish dairy sector, has the opportunity to be part of this transition by providing security of feedstock to AD plants. This would create a new and stable income stream for farmers, increase the sustainability of Irish agriculture, heat and transport through enabling the large-scale commercial development of AD and bioenergy production.

Recommendations to Mobilise Ireland's AD Potential

In order to fully activate Ireland's AD potential and accelerate the development of the industry coordination among investors, developers, cooperatives, government, and the planning system is required.

A wide-scale deployment of AD in Ireland requires the following:

- Certainty of feedstock supply & preconditions regarding the operations of AD plants.
- Certainty of price of gas for investors through the provision of long-term contracts.
- Certainty regarding the planning and regulatory environment.
- A strong statement of Government support for AD applications to the RESS

The opportunity to capitalise on this flexible green, sustainable and circular technology awaits. By enhancing the planning and regulatory systems and increasing the RESS focus on AD and bioenergy production, Ireland can create a facilitate investor environment and consequently resilient, cooperative and sustainable communities.

Report

What is the Bioeconomy?

» The bioeconomy relates to *"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"*.

» The bioeconomy will play a key role in contributing to climate change mitigation, rural and economic development.

» Anaerobic Digestion is one part of the bioeconomy and one part of the solution to socio-economic and environmental issues in Ireland.

Climate concerns and societal and industry dependence on finite fossil fuels is pushing the transition towards developing the bioeconomy through sustainable development. Additional challenges of land and eco-system degradation, a growing population and food insecurity are forcing the world to seek new systems of sustainable production and consumption[16].

The European Union's role in facilitating this great societal transformation is critical in improving its economic standing and the prosperity of its citizens in a highly competitive global economy[17]. The European Green Deal is a flagship initiative that is vital to pivoting the entire EU economy towards sustainability and circularity[18]. The devastating impacts of decades of dependence on non-renewable fossil fuels with a high carbon footprint are being realised internationally. In order to meet the EU's target of generating 32% of its energy from renewable sources by 2030 and ultimately achieve a carbon-neutral economy by 2050, the transition away from fossil fuels towards alternative, renewable energy sources in order to reduce greenhouse gas emissions (GHGs) and generate a circular bioeconomy must be at the forefront of international, national, and local policies[19].

The concept of the circular economy has recently gained traction in the world of sustainable development. Its roots can be traced back to an essay by Kenneth Boulding in 1966, in which he refers to managing the economy like a spaceship rather than an open system whereby, *"man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form."*[20] The linear pattern of production that has been the status-quo for years is no longer politically or socially acceptable. By closing the loop within the system, the economy and the environment can exist in equilibrium, while also adding social value. In order to accomplish this, a circular economy must focus on increasing resource efficiencies while placing a specific emphasis on agricultural, urban, and industrial waste[21].

The bioeconomy encompasses aspects of the green and circular economy and must fall within the principles of sustainability. While it is defined differently around the globe the following understanding, utilised in the 2015 Communique Global Bioeconomy Summit, is shared by many: *"bioeconomy as the knowledge-based production and utilization of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors."*[22]

The European Commission take a more activity and sector-based approach to defining the bioeconomy as: *"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,"* operated by, *"the sectors of agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries."*[23]

With an annual turnover of EUR 2.2 trillion and 18.6 million people employed within the bioeconomy in the EU[24] it is a matter of environmental, economic and social sustainability that is pushing the bioeconomy agenda forward internationally. It is considered to be central to solving global and EU challenges regarding rural development, employment and job growth, climate change, food security and resource exhaustion[25]. By turning bio-waste, residues and discards into valued resources, the development of the bioeconomy will aid in reducing GHG emissions, managing natural resources sustainability, ensuring energy security, and reducing dependence on non-renewable resources, in particular oil and phosphorus[26,27].

The 2015 Communique of the Global Bioeconomy Summit contends that in order to ensure a sustainable and circular bioeconomy a systemic approach across all sectors (i.e. nexus thinking) is required[28]. Innovative policy measures are needed to ensure efficient and optimal bioeconomy value networks that reduce waste and losses[29]. Through innovations, policy instruments, and incentives, its development has the potential to reduce food waste produced by retailers and consumers by 50% by 2030[30].

It is estimated that one third of food produced globally is wasted annually, resulting in vast socio-economic and environmental impacts. With population and energy demands projected to increase, annual waste produced is expected to increase 70% by 2050[31].

Within Ireland animal slurry is one of the country's most underutilized resources[32] of which 40 million tonnes is produced annually[33], further contributing to GHG emissions. In order to combat these forces, achieve carbon neutrality, and ensure the long-term competitiveness of Ireland, circularity must become mainstreamed into the economy and the nation's energy system[34].

The role of anaerobic digestion in utilising Ireland's waste resources is one part of the system and one part of the solution to overcoming the vast socio-economic and environmental issues Irish society is facing today.

What is Anaerobic Digestion?

» Anaerobic Digestion breaks down organic, biological matter to create a renewable energy source biogas, and a bio-fertilizer.

» Biogas can be upgraded to biomethane, which can be injected directly into the grid or used as a transport fuel.

» Support and subsidy schemes directed at anaerobic digestion and biomethane are required to overcome the high capital costs.

Anaerobic digestion is a technology that breaks down organic matter referred to as feedstocks, such as food waste, sewage, grass silage and animal slurry, in an oxygen-free environment to generate a renewable energy source, biogas[35]. The gas is comprised of methane, CO2, and other trace gases. The methane alone possesses an energy content between 50 to 55 MJ/kg[36]. Biogas can be used to replace fossil fuels in generating heat or electricity or combined in heat and power (CHP) units[37]. When it is upgraded to biomethane (renewable gas), a gas with a higher methane to carbon dioxide ratio by adding hydrogen through methanation reactions, the versatile energy can also be used as a renewable fuel in transportation[38]. It can further be fed, stored and distributed via the gas grid, replacing natural gas and other fossil fuels[39]. Additionally, AD offers a valuable by-product, digestate, a nutrient rich organic fertilizer with greater short-term effects[40]. The valuable farm fertilizer reduces the need for inorganic fertilizer use comprised of non-renewable resources[41].

AD allows for waste to be repurposed as a valuable, multidimensional renewable resource providing flexibility for potential projects. The agriculture industry produces ample residues that can be utilised locally as feedstocks for AD, thus reducing waste and GHGs and generating a circular economy[42].

On-farm AD additionally has the potential to positively impact rural development through job creation and an income diversification opportunity for farmers, reduction in odour associated with slurry, generation of heat and electricity for on-farm and community use, farmer return on digestate, and farmer empowerment[43].

The economic viability of generating biogas through AD, however, depends on a number of operating factors including the size of the digestor and feedstock availability, and support factors and subsidies schemes[44]. Unfortunately, in Ireland there are currently limited support schemes directed specifically at AD plants. The high capital cost involved further reiterates the need for policy supports on all levels and favourable prices received for renewable energy produced[45,46].

How do we compare with other countries?

On a European and international level, advancements within the bioeconomy and AD have been ongoing for years. Sweden, Germany and the UK are all far ahead in the development of these sectors compared to Ireland. Several factors play into the success of these countries. With the clear European wide agenda towards pushing the bioeconomy forward, looking towards the leaders in this field will offer better direction towards this transition.

Sweden

» Sweden is an EU leader in the generation of renewable energy, with bioenergy accounting for 38% of total energy use.

» This is the result of Swedish society's principles of individual responsibility and successive years of supportive policy.

Sweden is considered one of the EU's leaders in the use of renewable fuels, with 52.6% share of energy from renewable sources in 2014 . The country is aiming to become the world's first fossil free country and is surely on its way with a number of cities and regions making the transition[48].

Sweden has been producing biogas from sewage sludge at wastewater treatment plants since the 1930s (still the single most contributing feedstock). By the mid 1990s as co-digestion plants were introduced, biogas was being produced from a number of feedstocks including waste from the agricultural sector, households, slaughterhouses, catering establishments and food processing industries.

In 2015, the country was producing about 1.95 TWh/year from 282 biogas plants, in which 187 GWh was derived from landfills[49]. Today bioenergy is Sweden's largest source of energy use, accounting for 38% of total energy in 2018[50]. The majority of biogas produced and imported into Sweden is upgraded to biomethane to be used for natural gas vehicles (NGV). The remaining biogas replaces natural gas use in industry and heating[51]. In 2018 the country made further GHG emission reductions through producing and utilizing 2.8 million tonnes of digestate. Of this, 2.4 million tonnes replaced mineral fertilizers in agriculture[52].

The progress Sweden has made in transitioning away from fossil-fuels is a result of several factors.

The Swedish model of a horizontal society evokes principles of empowerment, concern for others and the common good amongst individuals[53]. Swedish society is further tied to the notion of land and the natural environment as commons, in which *"each individual is entitled to use the natural environment freely, regardless of public or private ownership rights, provided the use is reasonable and restrained"*[54]. This concept of individual responsibility is embedded into the fabric of Swedish society and has shaped the way people have responded and changed their behaviours regarding climate change.

The wide-scale and successful development of this industry is additionally the result of ambitious targets and supportive policy measures, whereby years of successive governments have pursued policies to reduce the economy's dependence of fuel imports far ahead of EU policy[55]. The city of Växjö is an example.

Växjö, Sweden

» The city of Växjö, Sweden supplies 88% of total energy from renewables and is a leader in the bioeconomy.

» Consistent unanimity and financial support from the government, business community and Växjö citizens has made this possible.

» Significant environmental, social and economic benefits have been noted due to the city's progression in the bioeconomy.

The city of Växjö, Sweden is home to 85,000 residents, 36,000 students, and 8,000 businesses. Växjö is known as one of the greenest cities in the world, supplying 88% of total energy from renewables[56]. It is the first Swedish city to use biomass to supply a district heating network. In 2012 the city reduced its CO2 emissions by 41% compared to 1993, emitting 2.7 tonnes of CO2 per capita from electricity production, heating, and transport, whereby the EU average was 7.01 tonnes[57]. Through developing the city's bioeconomy, a 73% economic growth rate was seen between 1993 and 2010 along with the creation of 2,000 local jobs between 2011 and 2014. These efforts have all been made to aid Växjö in becoming a fossil fuel free city, a decision that was made very early in 1996[58], thus transforming itself into one of Europe's greenest cities.[59]

A number of factors played into the development and success of the city's transition, beginning in 1990 when the city made the decision to begin the energy and ecological transition process. The restoration of the local environment and Växjö's surrounding water bodies, then characterized by degradation and eutrophication[60], was the first environmental project that led the city down this fossil-fuel free path[61].

Considered critical to this success has been the strong involvement of all local players, a coherent long-term strategy, strong local potential for bioenergy along with the 1996 unanimous vote for a fossil free city[62]. These factors created a *"positive spirt of dialogue"* between political, economic, institutional and community stakeholders. In 1997 a framework to bring stakeholders from various sectors together to carry out projects that aided in the fossil free city goal was then created. The executive and technical departments were key to coordinating stakeholders and local actors and ensuring the sustainability of projects. The educational sector further worked on citizen behaviour, where it was decided that making life without fossil fuels easy was the way forward[63]. Rather than penalizing people they would be encouraged to participate. This included the provision of cheaper, more convenient district heating, more efficient transport services and more pleasant cycling lanes and pedestrian areas[64].

While it has not always been a perfectly smooth or linear path for the city, the constant unanimity, cooperation, and financial support made by the government, business community, and citizens themselves has led to a strong competitive edge through the bioeconomy. Today, the municipality of Växjö, the private sector and university work together to reach the cities objectives[65]. Necessary measures are financed through subsidies from the EU, Swedish government, and the municipality[66].

The direct benefits of this shift have been seen at all levels. Through biomass cascading value added generating activities Växjö has created a diversified and dynamic business community, increasing the attractiveness to investors, entrepreneurs, and skilled employees. Through support for bioenergy, district heating costs have been made stable and competitive compared to oil and electric appliances. Växjö's university is now internationally recognized as a centre of excellence on biomass[67].

The social impacts of these activities are highly visible. Växjö's population is growing, attracting over 1,000 new inhabitants yearly from Sweden and around the world. Improvements in the surrounding natural environment, public transport, cycling facilities and pedestrian areas have increased access to green spaces, further improving the quality of life of Växjö's citizens. Social cohesion has been reinforced through increased dialogue between politicians and the local population via discussions organised directly in neighborhoods. The value of networking has become embedded into the fabric of private, public and community actors highlighting the value in engaging citizens in this urgent sustainability transition. Ecology and the economy are seen as one through resource management, a green budget, and a circular economy[68].

The UK

» The UK currently has 579 operational AD plants, including 88 biomethane-to-grid plants, with an additional 331 AD projects under development.

» Support schemes including the Feed-in Tariff, Renewable Heat Incentive, and the Renewable Transport Fuels Obligation have facilitated the industry.

» A favourable regulatory environment and advocacy groups have also been critical to this success.

With similar socio-cultural and economic environments to Ireland, an analysis of the UK's anaerobic digestion sector will assist in recognizing what is needed to accelerate the Irish industry.

The most recent 2020 figures of the UK's AD industry reveals the country has 579 operational AD plants, including 88 biomethane-to-grid plants, with an additional 331 AD projects under development[69]. The UK's strongly developed industry is the result of various policy supports and strong local potential.

A number of incentive schemes are available for the development of AD in the UK, including the Feed-in Tariff (FIT) for electricity and the Renewable Heat Incentive (RHI) that supports heat produced from biogas combustion and biomethane injection into the grid[70]. All incentives are supported for 20 years, guaranteeing long term contracts for suppliers. The Renewable Transport Fuels Obligation supports the use of biomethane as a transport fuel[71]. This incentivisation to produce bioenergy through a diverse mix of outputs is considered critical to ensuring resilience and stability when faced with market shocks[72].

Additional regulations regarding the management of animal manure have led to an increase in manure management plans among farmers, whereby on-farm AD has been considered the primary management tool[73]. AD development across the UK is recognized as an important element to balanced regional development. It is further supported through the Rural Communities Renewable Energy Fund that provides funding for pre-planning and approval of regional projects[74].

While these domestic policy instruments have been critical to the development of on-farm AD, the realized benefits of the industry are further a result of strong cross-departmental integration and cooperation across all government levels and institutions. The establishment of the Waste and Resources Action Plan (WRAP), a not-for-profit organization that advocates for a resource efficient and circular economy, has been recognized for its role in developing soft policy measures that have simplified AD planning and operation permit process, and the provision of technical resources for potential AD developers[75,76]. Through their advocacy and support WRAP has played a central role in making the development of AD plants easier, inspiring leaders in the field.

Germany

» Germany is a leader in biogas production in Europe, representing 50% of total biogas produced.

» Germany's feed-in tariff for renewable electricity which prioritises AD development has greatly increased the adoption of agricultural AD technology.

» The country's overall policy framework has further impacted the adoption of AD.

Germany has been a pioneer in agricultural Anaerobic Digestion since the early 1990s with the introduction of a stable FIT or Erneuerbare Energien Gesetz (EEG – Renewable energy legislation)[77]. The FIT subsidises AD through the provision of long-term 20 year contracts which compensates the farm for the investment in generating renewable electricity. By remaining stable over time, this policy has greatly increased investments in AD technology and decreased operation costs[78]. The FIT prioritises AD development, providing installations with higher rates than wind energy, landfill gas and hydropower[79]. It further ensures generators priority access to the grid[80]. Additional incentives include bonuses for using selected feedstocks including manure, garden and plant biomass, and crop residues[81].

Further, the abundance of AD feedstock has greatly impacted agricultural AD adoption rates[82]. Amendments to legislation in 2004 provided a bonus for the use of energy crops as a feedstock in AD. This resulted in an increased demand for them, requiring the use of one fifth of arable land or 23 billion square meters, thereby negatively impacting biodiversity. To rectify this the legislation was once again amended in 2011 to discourage large scale AD plants, favouring smaller plants. There are now stricter regulations over the use of energy crops and the amount of energy derived from AD[83].

Similar to Sweden, Germany's overall policy framework has increased the adoption of agricultural AD including ambitious state-level targets for renewable energy production and a landfill ban for untreated biologically degradable organic waste[84]. The Market Incentive Program (MAP), which was introduced in 1992, provides grants covering up to 30% of the costs for new AD projects. While this policy framework has positively impacted the development of AD in Germany, the FIT is still considered to have had the greatest influence[85].

Currently Germany has the highest rate of biogas production in Europe with around 9,000 farm-scale plants (165 feeding into the natural gas grid)[86], representing 50% of total biogas production in Europe[87]. While the most common application of AD is CHP, other support measures are being introduced to encourage biogas upgrading to biomethane including the introduction of a bonus for biomethane production[88].

Today the FIT mostly favours small to medium-scale farm installations and larger AD plants for waste digestion[89]. With this, Germany has seen an increasing number of bioenergy villages, entire rural municipalities seeking to meet their energy demands through biomass. These villages contribute greatly to rural development, climate change mitigation, and to Germany's energy transition[90].

Does Irish Policy Support Anaerobic Digestion?

Irish policy does support the development of anaerobic digestion in principal, but it falls short of delivering meaningful volume in practice. It is clear that if we are to meet our climate targets this agenda will have to be moved on considerably.

Climate Case Ireland, Friends of the Irish Environment CLG vs. The Government of Ireland, Ireland and the Attorney General, 31st July 2020. The Supreme Court has quashed the 2017 National Mitigation Plan, ruling that it falls short of what is needed to reduce the country's GHG emissions, calling for a more ambitious and action-specific plan outlining how the country's 2050 targets will be met[91].

The Renewable Electricity Support Scheme (RESS) is an auction based scheme offering support to renewable electricity projects in the Republic of Ireland[92]. The first round of approvals was published in August 2020 with no successful biogas projects[93]. (To be discussed in detail in a subsequent section)

The Climate Action Plan outlines a course of action for Ireland to address the climate change crisis and ultimately tackle it. Within the plan, support for biomass mobilisation and anaerobic digestion are referenced[94].

The Renewable Energy Directive II (RED II) sets the overall EU target for Renewable Energy Sources consumption by 2030 for 32%[95].

The Bioenergy Action Plan for Ireland sets out a strategy for the successful development of bioenergy and the delivery of its associated benefits across agriculture, enterprise, transport, environment and energy sectors[96].

Ireland's National Policy Statement on the Bioeconomy reflects the government's vision of making Ireland a global leader in the bioeconomy, moving beyond target compliance and carbon mitigation towards a carbon neutral and circular economy. As the first policy statement, it remains broad, touching on the key principles underpinning the bioeconomy: the sustainability principle, the cascading principle, the precautionary principle and food first principle (to be defined in a subsequent section). The policy statement additionally identifies the key actions needed for the future development of the bioeconomy in Ireland including infrastructure needs, cross-sectoral collaboration, the growth of relevant markets, and the need to strengthen engagement to ensure coherence across all sectors[97].

The Support Scheme for Renewable Heat, run by the SEAI, provides supports and grants for the generation of renewable energy for heating systems including that of biomass boilers and AD plants[98].

The Biofuels Obligation Scheme, administered by the National Oil Reserves Agency, requires fuel suppliers to reduce the carbon intensity of fuel supplied to road vehicles and non-road mobile machinery by 6% by 2020. The certificate-based scheme requires that every oil company and oil consumer is liable to pay the NORA levy, ensuring a 12.359% volume of biofuels is present[99].

What does the Government have to say?[100]

The new Programme for Government, *"Our Shared Future"* sets out Ireland's policy commitments over the next five years. While COVID-19 has presented immense challenges and devasting consequences, it has offered the nation an opportunity *"to implement radical policies that were considered impossible before"*.

» Goal to reduce the nation's GHG emissions by 51% over the next decade.

» Several key policy areas within the Programme offer the opportunity to support AD development.

The nation has committed to a 51% reduction in GHG emissions over the next decade with the ultimate goal of net zero emissions by 2050. In order to meet these targets agriculture, the built environment, energy, and transport will need to fully decarbonise or even deliver negative emissions through carbon sinks and innovative technology[101]. A recent unanimous supreme court ruling, however, ruled that the government's national climate action plans fall short of what is needed to meet the county's commitments, calling for a more ambitious plan specifying how these 2050 targets will be met[102].

Under the Green New Deal and Balanced Regional Development missions, the government has promised to fulfil several key policies in relation to energy and decarbonising agriculture. The role of sustainable bioenergy will be central to reducing the use of inorganic nitrogen fertilizers and to the implementation of the National Waste and Circular Economy Action Plan. In order to do so the role of community energy and Ireland's on-farm anaerobic digestion potential will be explored and developed. This is further reinforced through the retraction of support for imported fracked gas. An additional ban on the exploration for offshore gas would further the government's commitment to reducing GHGs, allowing for indigenous biogas to replace imports and increasing security of energy supply once the Corrib gas field is depleted.

The Programme recognises the difficulties and uncertainties the agriculture sector in Ireland has faced over recent years, including Brexit, COVID-19, changes to the Common Agricultural Policy (CAP), unforeseen weather events, and market disruptions in the beef sector. Building resilience to overcome these challenges will require research and innovation in the agri-food sector that focus on environmental sustainability and the bioeconomy, and investments in on-farm renewable infrastructure through the implementation of the National Policy Statement on the Bioeconomy. Additionally, the Programme will seek reforms to CAP that incentivise farmers to sequester carbon, improve biodiversity, water, and air quality, and produce renewable energy. This will all be supported through the development of results-based support schemes, including the establishment of an Energy Efficient Farming scheme.

While the new Programme for Government offers a distinct opportunity to progress AD through supportive policy, there is lack of detail on how this sector will be developed. This agenda places energy and agriculture as a central focus to achieve carbon neutrality by 2050, reiterating that this is the time for profound change. With continuously rising emissions a supportive AD plan for Ireland must be developed.

Does anaerobic digestion have a role in Ireland reaching Net Zero by 2050?

» Republic of Ireland's population is projected to rise to 6.7 million by 2051.

» EirGrid forecasts a 32% growth in electricity demanded over the next decade.

» Ireland has made the second lowest progress out of the EU-28 in reaching GHG and renewable energy targets.

» Ireland's substantial Agri-Food industry is a pivotal economic driver, making it a highly appropriate location for renewable gas production.

The future of energy and electricity generation requires an extensive systems and societal transformation. With unequivocal evidence of the devasting damage of fossil fuels on the planet, measures are in place to phase them out within the next decade. The population of the Republic of Ireland is expected to increase to 6.7 million by 2051[103], this paired with anticipated economic growth will inevitably result in increased energy demands. EirGrid forecasts a median electricity growth of 10TWh over the next decade, a 32% increase from today[104]. Systems will be required to carry more power than ever before, with the majority of it coming from renewable sources[105].

As the country is not on track to meet its EU 2020 GHG emissions and renewable energy targets, a considerable amount of new renewable generation will be required to close the gap for future targets[107,107]. Under the EU Renewable Energy Directive 2 (RED II) Ireland is required to provide at least 16% of gross final energy consumption from renewables (RES). However, the country has made the second lowest progress out of the EU-28 in reaching 2020 targets, supplying only 11% RES, with heat and transportation targets proving especially challenging[108].

With GHG emissions not on target, future emission targets for 2030 and 2050 are already posing a great challenge[109]. According to the Central Statistics Office, agriculture accounts for the highest share of emissions in Ireland, accumulating to 33% of overall emissions, followed by transport at 20% and electricity generation at 19%[110]. Due to the country's substantial agricultural industry which is mainly focused on beef and dairy systems, Ireland has the highest portion of overall emissions from agriculture, compared to the EU average of 10% [111,112]. Decarbonising agriculture, transport and heat are of critical importance to meeting targets and transitioning to a sustainable economy[113]. The value of bioenergy in decarbonising these sectors and reaching required targets is recognised throughout the EU, with demand for increased bioenergy development evident in several policy documents, including Gas Networks Ireland 2050 Vision, EirGrid's 2020-2025 Strategy and the Renewable Electricity Support Scheme (RESS).

Gas Networks Ireland Vision 2050[114]

» Gas Networks Ireland is planning for a carbon-neutral gas network by 2050.

» Biomethane will play a central role in realising this vision.

» This vision needs to be supported by better RESS.

Gas Networks Ireland (GNI) vision for 2050 encompasses a net zero carbon gas network for Ireland, through the decarbonisation of heat, transport and agriculture. GNI highlights biomethane as a key driver in delivering this vision, in which it is estimated to account for 37% of the gas network by 2050. The benefits of this envisaged system include immediate emissions savings, low cost and minimal disruption transition, increasing energy security and flexibility, the decarbonisation of HGV's and bus transport, and a robust stimulated rural economy.

The use of biomethane in the gas network has high potential being compatible with the current gas network infrastructure and suitable for the same applications. GNI is pursuing an additional 11TWh/annum of renewable gas (biomethane) in the network by 2030, accounting for 20% of current demand, and 22TWh/annum by 2050 (40% of current demand). Currently, network development of renewable gas injection points is afoot as GNI works with critical stakeholders, including Teagasc and MaREI, in order to collaborate with farmers and communities in developing Ireland's renewable gas industry. Further infrastructure investments are underway, including Compressed Natural Gas (CNG) and Bio-CNG refuelling stations for HGV's and buses, with the first public CNG station developed at Dublin Port. GNI are further working with stakeholders to develop a 170-station CNG refueling network across the country. They anticipate network decarbonization will require the availability of Bio-CNG in order to further reduce transport emissions. However, adequately GNI's vision is currently not supported by a government. Stronger support for renewable gas within the RESS is vital to delivering GNI's vision of a net zero carbon gas network.

EirGrid Strategy 2020-2025[115]

» EirGrid is preparing for a systems transformation in order to accommodate an increased supply of renewable electricity and reach future RES-E targets.

» This strategy is supported by the Renewable Electricity Support Scheme (RESS)

The demand for renewable energy sources has been amplified by EirGrid in their 2020-2025 strategy, seeking to lead the way towards a carbon-free electricity system. The independent entity anticipates the increased demand for power in the coming years, recognizing the role renewable sources will play in combating climate change and transitioning to a sustainable, circular society. This transition will require a power system transformation that can accommodate nearly 100% renewable energy, while ensuring a constant, reliable and competitive electricity supply. In order to achieve 2030 RES-E targets the group foresees an additional 10,000 MW of additional renewable generation will be required. Currently, the grid has the capacity to operate with 65% of renewable power, by 2030 the system must be able to accommodate 95%. This transformation requires innovative solutions and technologies, infrastructure improvements and system interconnection between North South, Celtic and Greenlink Interconnectors. EirGrid is preparing the Single Electricity Market to allow for an accelerated growth in renewable electricity generation, in which a 23% increase will be required. These preparations will be supported by the Renewable Electricity Support Scheme.

Renewable Electricity Support Scheme[116]

» The Renewable Electricity Support Scheme will provide supports to deliver up to 70% renewable electricity by 2030 through a mix of technology.

» The scheme will be supporting both developer and community-led proposals.

» The scheme is highly weighted towards solar and wind; further support for AD and biomethane generation within the RESS scheme is needed.

Through European and Irish legislation, the demand for biogas has been recognised. The Renewable Electricity Support Scheme (RESS) seeks to provide a broad range of policy objectives, including community ownership and participation, increasing technology diversity through a broad and technology neutral renewable electricity mix, the deliverance of ambitious targets and increasing the sustainability and resilience of Ireland's energy sector. With an estimate budget of at least €7.2 billion over the next five years the scheme has received approval from the European Commission under EU State aid rules[117]. It is considered an significant step in facilitating Ireland's transition to carbon-neutrality.

The RESS will provide the supports to deliver a renewable electricity (RES-E) target in Ireland of up to 70% by 2030 in accordance with the National Energy and Climate Plan (NECP), under the Renewable Energy Directive (RED II) and the Governance Regulation under the EU Clean Energy Package. The ambitious targets will contribute to the EU-wide binding renewable energy target of 32% by 2030.

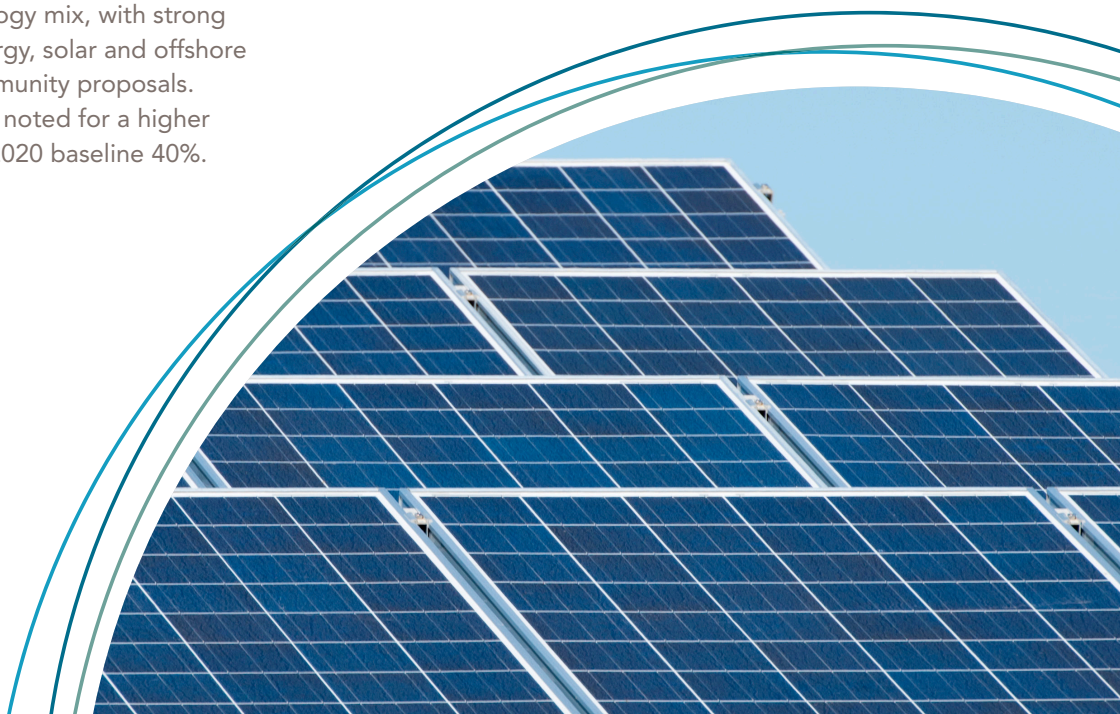
The scheme is based on a cost-effective framework that will provide supports for projects through periodically run competitive auctions, allowing for a diverse and neutral renewable electricity technology mix. It will allow for opportunities for several technologies including biogas, solar PV, and onshore and offshore wind. Successful projects will receive support through 15-year contracts in the form of a premium on top of the market price. While this competitive auction framework allows all eligible technologies to compete, preferential treatment has been given for a small quantity of solar and wind energy, both intermittent, non-dispatchable energy sources. The results of the first 2020 auction revealed there has been no allocation of RESS funding to anaerobic digestion or bioenergy, reinforcing the need for increased attention and support for this dispatchable technology in Ireland[118].

A public consultation on the design of principles of the RESS in 2017 received 1,250 submissions, 1,000 from individual citizens with the remainder from community groups, energy companies, the renewable energy sector, political parties and other government departments. The consultation revealed strong support for increased diversity in Ireland's renewable technology mix, with strong industry support for bioenergy, solar and offshore wind, especially within community proposals. Further, strong support was noted for a higher RES-E ambition above the 2020 baseline 40%.

During the economic appraisal underpinning the RESS, Cambridge Economic Policy Associates modelled technology and capacity scenarios with increasing RES-E ambitions (40% - baseline, 45%, 50%, 55%). In order to meet Ireland's 2030 RES-E targets and the increased ambitions outlined under the new RESS. Compared to maintaining the baseline scenario, CEPA estimates that the country will need to double its RES-E capacity in order to meet the 50% RES-E scenario, increasing it two and half times to meet the 55% RES-E scenario.

Currently, Ireland's RES-E generation accounts for 3,500MW. In order to meet 2030 RES-E targets, Ireland's National Development Plan (NPD) established that an additional 4,500MW of RES-E will be required. However, the RESS EU State Aid submission is proposing a 55% RES-E ambition, equivalent to 11,000-12,000 GW/hrs. EirGrid's Tomorrow's Energy 'Community Action' Scenario aligns with these ambitions, advising further development of onshore wind and bioenergy projects in order to meet these goals[119].

The RESS scheme combined with the power and gas networks ultimate transformation emphasize the rationale for increased bioenergy support and development. Ireland can no longer solely focus on wind energy, an intermittent source. Through a diverse renewable technologies mix, power generator scan better meet energy demand, RES and GHG targets, and the transition to a sustainable society.



What Anaerobic Digestion activity is there in Ireland right now?

While Ireland's bioeconomy is still under development, the potential and demand for it is slowly being recognised by a number of progressive entities. The following provides a flavour of what has already been achieved and of how the industry could develop in a variety of ways.

Carbery Group & Biorefinery Glas

Biorefinery Glas is a small-scale farmer-led European Innovation Partnership (EIP) that is supporting farmer diversification into the circular bioeconomy through green biorefineries. The project is funded by the Department of Agriculture, Food and the Marine under the 2014-2020 Rural Development Programme. During the summer of 2019 a mobile grass bio-refinery was demonstrated in West Cork farms through Carbery's West Cork cooperative network. The biorefinery converts freshly harvested grass into a range of value-added products, including cattle feed fibre and a grass whey for fertiliser or bioenergy applications. Expected outcomes from the project include a 25% reduction in nitrogen emissions and a new financially viable business model for farmer diversification. The small-scale farmer led design of the project offers a viable model that has the potential to be replicated throughout Cork and Ireland. By keeping the production of biogas close to the farmer, greater benefits, control, and therefore greater incentives for development can be obtained[120].

Carbery Group is focused on ensuring sustainability as their core business strategy. Intuitively, by operating through the cooperative principles, the group works to guarantee economic viability and social responsibility[121]. Founded in 1965 with its headquarters in Co. Cork the co-op has grown to achieve international recognition, with 8 facilities globally and 660 employees. In 1979 the group developed the 'Carbery process' to convert whey permeate into bioethanol. Today Carbery produces 12 million litres of bioethanol which is used in the drinks sector and increasingly as a biofuel due to its very low carbon intensity. Then in 1982 Carbery developed Ireland's first commercial AD plant at the group's headquarters in Ballineen. Using the stillage, or liquid waste, from the bioethanol process as the feedstock the plant is able to fulfill 9% of the sites steam requirements, displacing significant GHG emissions in the process.

Dairygold Group Anaerobic Digestor

Dairygold is the largest dairy cooperative in Cork with 7,000 shareholder members[122]. The group was formed in 1990 through the amalgamation of two dairy cooperatives. Dairygold focuses on collecting and processing milk and supplying members with agricultural inputs e.g. fertilizer. The group is renowned globally for its sustainability measures. Dairygold in partnership with the SEAI has developed their own AD plant at Castlefarm, Mitchelstown, Co. Cork. [123].

As one of the largest plants in Ireland it treats 27,000kg of wastewater per day from powder milk and cheese production wastewater and high-strength salty whey[124,125].

The plant converts the wastewater into energy-rich biogas and a small amount of waste biomass (sludge). The high-quality anaerobic effluent feeds the existing downstream BNR system. The reactor collects the generated biogas and is used in a dual-fuel boiler to produce hot water to heat the reactor, while a portion is converted into renewable energy[126]. *"Thus Dairygold achieves energy efficient treatment and produces additional energy from excess biogas."* [127]

Through this niche development the group has achieved a number of benefits. Over a period of 29 months the reactor helped save €871,234 while also offsetting 5822 tCO2[128].

Graze Project

Gas Networks Ireland GRAZE Gas Project seeks to deliver up to 56,000 homes with renewable gas (biomethane) through the natural gas network, potentially supplying 6,500 jobs for rural Ireland. Located in Mitchelstown, Co. Cork the project is a critical component of GNI's vision to decarbonize. The project will include the development of a Central Grid Injection (CGI) facility for renewable gas injection, further supporting the development of 20 farm-based AD biomethane plants within a 50km radius, utilizing animal waste, slurry, municipal waste and grass. The Mitchelstown facility will be the first of 17 connected facilities delivering biomethane into the natural gas network. The facility will be the second of its kind in the country, with the first being at Cush in Co. Kildare.[129,130,131]

Ashleigh Farms & Ashleigh Environmental

Ashleigh Farms in Dungarvan, Co. Waterford generates biogas through their own on-farm biogas plant, built in 2017. Through the plant, the farm is able to generate approximately 70,000m3 of renewable biogas from 9,000m3 of pig slurry per year. The farm states they have reduced their CO2 eq by up to 390 tonnes (435 kg CO2 eq per sow per year is produced on an Irish pig farm), a 37% reduction of total CO2 eq output per year. Further benefits noted by the farm is a reduction in odour associated with slurry, and the utilisation of the nutrient rich organic fertilizer, digestate, by local farmers[132].

In 2015, Ashleigh Farms created a spin out entity Ashleigh Environmental to develop Anaerobic Digestion Pre-Treatment technology. Over the past number of years the company has worked with its European partners to develop their Biowave™ technology, which uses industrial microwave processing to enhance renewable biogas yields from organic wastes in the agri-food, waste water and large primary agriculture sectors. The application of microwaves to pre-treat biomass is one of the most promising valorisation techniques. In addition, microwave treatment has shown to be an effective and promising way to sterilise wastewater, improve dewaterability and enhance nutrient recovery[133]. Ashleigh Environmental was the overall Research & Innovation winner at the 2019 SEAI Sustainable Energy Awards and has recently been awarded funding through the Governments Disruptive Technologies Innovation Programme to develop its technology on a large dairy plant in Ireland.

Agrocycle[134]

Agrocycle is a Horizon 2020 research and innovation project that presents a blueprint and EU policy protocol for instilling the circular economy into the agri-food sector through recycling and valorisation of agri-food waste. The project is led by the School of Biosystems and Food Engineering at University College Dublin and seeks to identify and deliver sustainable pathways for waste valorisation in accordance with EU target of reducing food waste by 50% by 2030. The project offers a knowledge-based and educational marketplace through the Agrocycle joint Stakeholder platform, taking into account an inclusive analysis of food waste value chains including, livestock and crop production, food processing and the retail sector. The platform further delivers practical examples and appropriate applications for agri-food waste including biofuels, high value-added biopolymers, energy, and microbial fuel cells. Within Ireland, however, there has been no activity since May 2019.

What is Ireland's Anaerobic Digestion Potential?

» There is immense untapped potential in Ireland.

» There is the potential to create €1.5 billion in direct investment through AD development along with significant environmental benefits.

Within many European countries, AD and the production of biogas has been supported by policy for many years. AD in Ireland has yet to receive the attention and policy support needed to accelerate its development, leaving the country falling behind many of its EU counterparts. Studies, however, have shown that Ireland has the highest potential for biomethane production per capita within the EU[135]. With a strong agricultural sector that devotes 2/3 of land to agricultural use, comprised of 140,000 individual farms and accounting for 5.7% GDP, Ireland boasts comparative advantages in this sector[136]. This extensive biogas potential comes from various resources including, grass silage, slurry, food waste, sewage sludge, seaweed, and organic fractions of municipal solid waste (OFMSW)[137]. Co. Cork in particular holds the highest potential for AD feedstock in the country, boasting the largest number of dairy cows at 378,200 head[138].

A 2012 IrBEA study found the following economic benefits from the deployment of bioenergy infrastructure in Ireland[139]:

» The creation of 3,600 new permanent jobs;

» €1.5 billion in direct investment;

» The generation of over 8,000 work years during construction and installation;

» Securing family farm income through farm diversification;

» A reduction in Ireland's energy import bill by 7.5per cent; and

» The provision of a secure and competitive indigenous energy source for Irish homes and business.

Additional potential benefits to developing Ireland's AD and biomethane industry include:

» Saving over 2.6m tonnes of CO2 emissions per annum[140].

» 35% to 48% reduction of Irish agricultural GHG emissions[141].

» Utilisation of 4.8m tonnes of animal slurry per annum[142].

» Decarbonisation of industry, domestic heat, and transport.

» The transitioning of Ireland into a global circular economy leader.

These latent economic and environmental benefits that could be activated from embedding this circular technology into the country's energy system have been recognised by Cork's business community through the Sustainable Cork Programme, Building Economic Resilience Report[143]. Capitalising on this green energy is critical to boosting our local and national green credentials and enhancing the regions attractiveness to FDI.

What feedstock do we have for Anaerobic Digestion?

» A feedstock is essentially the fuel for anaerobic digestion.

» Choosing AD feedstocks must be done on a territorial basis.

Feedstock is essentially the fuel for anaerobic digestion. It can be a wide range of materials from agricultural slurry, to sewage sludge, food waste, agricultural residues or grass. AD plants can co-digest multiple organic wastes in one digester that are compatible with one another, thereby increasing the methane production from low-yielding feedstocks[144]. Identifying the best combination of feedstocks for AD plants is a critical factor in accelerating biogas production. AD plants must be fed constant and consistent diets in order to maintain their functionality. They cannot be over or underfed.

The chosen feedstocks for each plant must keep in line with Ireland's National Policy Statement on the Bioeconomy and the key principles underpinning it: the sustainability principle, the cascading principle, the precautionary principle, and the food first principle[145].

1. The sustainability principle places environmental sustainability at the heart of the bioeconomy.

2. The cascading principle, whereby priority is given to higher value applications that allow the reuse and recycling of products such as food, biobased materials and chemicals, before energy and fuel generation.

3. The precautionary principle is a risk management approach with four main components: *"taking preventive action in the face of uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternatives to possibly harmful actions; and increasing public participation in decision making."*[146]

4. Finally, the food first principle which ensures food security.

Each feedstock and their potential combinations must be considered on a territorial basis with an assessment of where resources are based around the country. Feedstock competition costs and how they change over time must also be considered in order to ensure a consistent and constant flow of feedstock. For example, during times of drought the value of grass/fodder increases, thereby affecting the availability of this resource as a feedstock. The EU Renewable Energy Directive's (RED II) sustainability criteria should be reviewed prior to any other sources as a starting point regarding ethical and technical considerations for feedstocks. Regardless of the potential feedstock mix, it is clear there is immense potential for AD and the production of bioenergy in Ireland.

Grass

When considering grass silage as a potential feedstock the fuel vs. food debate and other farm concerns, such as drought potential, must be considered. With Bord Bia initiating a new grass standard whereby 95% of feed for cows must come from grass, the amount of grass that can be used for AD will be limited. In order to keep in line with the bioeconomy principles outlined above, avoid greenwashing and ensure circularity, feed must always come first and fuel second. Incentives in the grass systems are required in order to encourage farmers to use surplus grass silage for AD, in particular for the beef sector. There is potential to substantially increase the amount of grass silage that could be available as an AD feedstock through better grass management practices[147]. The Glas biorefinery project, which was trialed in West Cork through Carbery Cooperative dairy farmers may also present a means to overcome this challenge[148].

Slurry

Livestock slurry in Ireland is one of the most widely available and underutilized resources [149], with 40 million tonnes produced annually[150]. The use of slurry from cows as an AD feedstock poses logistical challenges. As cows spend approximately 9 months out of the year grazing, collecting their slurry presents obstacles. To overcome this, innovative processes and technology in slurry collection will be required. The use of slurry from pig and poultry animals, however, poses fewer challenges as this can be easily collected year-round. The collection and utilization of pig manure is currently being undertaken by Ashleigh Farms in Cappagh, Co. Waterford. The use of pig manure is highly logical as it is the most widely consumed meat in the world and its production is anticipated to increase by 40% in the coming decades[151].

Food Waste

Using food waste will require changes in food waste collection systems, which are currently being under-utilised[152]. Using food waste to feed AD plants is better suited to urban regions and may face barriers as waste is heavily regulated by the EPA.

Sewage Sludge

There are opportunities for synergies with Irish Water through the utilization of sewage sludge as an AD feedstock. There are currently 1,000 wastewater treatment plants in the country, all producing sewage sludge. Sustainable treatment of the sludge is required to *"ensure its safe and efficient re-use or disposal"*[153]. This valuable resource has a high energy content and is especially valuable for agricultural land use[154]. Throughout the National Wastewater Sludge Management Plan (NWSMP) the treatment of sludge through anaerobic digestion is consistently highlighted.

Advanced anaerobic digestion in particular has been found to be the most economically viable option with the lowest carbon footprint for treatment, followed by the reuse of residual biosolids on land and energy recovery for wastewater plants. Through the National Sludge Hub Project there are currently 14 wastewater treatment plants in Ireland utilizing AD. Proposals have been made to increase the number of sites as the quantity of wastewater sludge produced is projected to increase by more than 80% by 2040. Irish Water's sludge management objectives will complement circular economy and climate action objectives. This model should be looked upon favourably.

Other

Additional feedstocks present an opportunity to increase the circularity and sustainability of Irish agriculture and the wider food industry, including wastes and residues such as dairy sludge, bakery and brewery waste, and crop residues.

Do Cooperatives have a role to play?

The success and strength of cooperatives in Ireland and their ability to provide secure continuity of various feedstocks for anaerobic digestion, means that they may have a very active role to play in the development of an anaerobic digestion industry of scale in Ireland.

With a concern for the community imbedded into the nature of the model, sustainability plays a central role in Irish agricultural cooperatives. Concurrently, Irish agriculture still accounts for 33% of overall emissions, the highest overall portion from agriculture in Europe[155,156]. As a predominately exporting country, Ireland will continue to play a vital role in food security, further increasing production and lengthening supply chains. The Irish agricultural sector is now under immense pressure to mitigate GHG emissions without threating food supply[157]. The role of cooperatives in assisting farmers in this endeavor is crucial to the future of Irish agriculture. The development of niche opportunities in farm-related activities is considered a key approach to ensuring sustainability for dairy and agricultural co-operatives in Cork[158]. There is an opportunity for Irish farmers and the catering industry to aid the country in its transition to carbon neutrality, through the process of anaerobic digestion and the development of bioenergy.

What is a Cooperative?

» Cooperatives are democratically controlled business structures, governed on the basis of seven principles.

» They act to empower members and communities.

Due to traditional market structures that benefit the few big players, cooperatives emerged to take back control and empower the smaller players, aiming to fulfil a social mission through an economic means[159].

"A Co-operative is a self-help business owned and democratically controlled by the people who use its services."[160]

Unlike firms solely operating for a profit, cooperatives are governed on the basis of seven principles developed by the Rochdale pioneers in the 1840s, highlighted within its definition[161].

1) Autonomous & independent
2) Democratically controlled
3) Open & voluntary membership
4) Member-economic participation
5) Education, training & information
6) Cooperation among cooperatives
7) Concern for the community.

These seven principles distinctly characterize cooperatives values. They operate within the social and solidarity economy, embodying collective over individual ownership[162]. They seek to address member, community, and human needs through self-help, equality, equity, transparency and solidarity[163]. They are further governed on the principle of one member, one vote[164]. While a cooperative is an enterprise, they emphasize service over profit with a concern of ensuring the triple bottom line[165]. Cooperatives are unique, as they are the only business model where ownership, control and benefits are bestowed entirely upon the user. The strong emphasis on their members enables cooperatives to ground themselves within the communities in which they emerge, thus concerning themselves with socio-economic justice and community development[166].

Within Ireland, cooperatives have a long and successful history in particular within the agricultural sector.

The Irish Cooperative Movement

» The Cooperative movement transformed Ireland and its rural economy.

» It is central to the sustainability of Irish agriculture.

» There is the opportunity to use it in a new way to stimulate and transform the Irish economy through the development of AD.

Ireland's strong agricultural background has led to the emergence of a strong dairy cooperative culture. *"Co-operatives as a business model have been imbedded in the Irish agri-business sector for well over a hundred years"*[167]. The Irish movement was first championed by Sir Horace Plunkett at the end of the 19th century. He is often considered to be the father of the Irish cooperative movement. At the time, dairy farmers were the backbone of Irish agriculture, but their fragmented and unorganised nature resulted in them being disempowered price takers, too small to be efficient[168]. Plunkett recognised the cooperative model as a way of modernising farming and empowering farmers to gain economic dependence from landlords and merchants. The first agricultural dairy co-operative in Ireland was formed in 1889. Five years later in 1894 Plunkett formed the Irish Agricultural Organisation Society (now known as the Irish Co-operative Organisation Society, ICOS) to offer support to co-operatives and to promote the movement[169].

Today the cooperative movement still plays an important role in Ireland, empowering members and communities, and instilling solidarity within and among them. They are a critical feature of both rural and urban life in Ireland, playing an important role in meeting human needs both economically and socially[170], facilitating rural and community development, job creation and economic growth[171]. The economic justifications to further strengthen the cooperative movement are immense. Cooperatives offer members the opportunity to capture profits from another level, a security of supply and greater market power[172]. The 2017 Second Global Report on Cooperatives and Employment for CICOPA emphasise the contributions cooperatives make globally, highlighting employment in particular. The report estimated that at least 279.4 million persons globally are employed in or within the scope of cooperatives, accounting for 9.46% of total world employment[173].

» Combined the global co-operative economy is larger than France's economy and would be placed right behind Germany as the 5th largest economy.

» 1 in every 6 people are estimated to be members of a co-operative.[174]

Within Europe there are 221,960 cooperatives with a total of 15,422,632 employed persons; 152,064,608 user-members; and 162,776,645 total members[175].

Within Ireland, CICOPA found there are[176]:

» 575 cooperatives

» 41,235 Employees

» 166,747 Producer Members

» 3,238,908 User Members

Of these 575 cooperatives, 331 are credit unions[177], 60 cooperatives are registered with the Irish Cooperative Organisation Society (ICOS) with 22 of them being dairy cooperatives[178]. ICOS *"is a co-operative umbrella organisation that serves and promotes commercial co-operative businesses and enterprise across multiple sections of the Irish economy"*[179]. Both Dairygold and Carbery Cooperative Societies are members of ICOS and play critical roles in ensuring the sustainability of Irish agriculture.

Recommendations: How do we mobilise Ireland's Anaerobic Digestion Potential?

While it is clear that Ireland has an abundance of untapped potential, immense agricultural resources and potential AD feedstocks, there are numerous constraints relating to financial viability, certainty over feedstock supply, lack of infrastructure, policy, regulatory and legislative barriers, market immaturity, and behavioural challenges.[180,181]

A wide-scale deployment of AD in Ireland requires the following:

» Certainty of feedstock supply & preconditions regarding the operations of AD plants.

» Certainty of price of gas for investors through the provision of long-term contracts.

» Certainty regarding the planning and regulatory environment.

Guaranteeing these levers will require coordination and cooperation among agricultural cooperatives, government policy, and the Irish planning and regulatory systems.

How can Cooperatives and agri-food best contribute?

» The cooperative model can enable large-scale commercial and farm-scale AD development and bioenergy production.

» Cooperatives are well placed to guarantee feedstock certainty.

» The role of cooperatives in rural social and economic development and in the sustainability of Irish agriculture should be grounded in the future CAP.

To date the deployment of AD in Ireland has fallen far short of its full potential. A study on Anaerobic Digestion potential in Ireland revealed 56 potential locations for grid injection equivalent to a 50 million EUR investment. For a large scale AD plant to be economically viable in Ireland it must generate at least 40 GWh of biomethane[182]. This requires a significant and consistent supply of feedstock, and operational and technical management of the AD plant. Large scale commercial operation will require cooperative involvement. Further, an important supply-side barrier not to be overlooked relates to farmer perceptions around risk and uncertainty of financing developing and running a plant[183].

Cooperatives offer numerous supports including negotiation power, marketing, funding, operational and technical management, and more[184]. A cooperative model for AD deployment via agricultural cooperatives would allow for scale and economic viability to be achieved, and the full utilisation of distribution networks. The cooperatives could further ensure certainty regarding feedstock supply, collecting the chosen feedstocks from individual farms. The cooperatives must be aware and plan for changes in feedstock competition costs, as the potential for generating bioenergy may distort feedstock values over time. For example, grass has the same value as fodder, this value increases during shortages. By introducing an alternative use for this resource which would then be valued against energy, there could be inflationary consequences for the monetary value of the feedstock. Cooperatives must foresee for such consequences to ensure consistency and sustainability of feedstock supply.

By operating via the cooperative model, the digestate derived from AD can be sold ensuring a return for the farmers. The generated biogas can be compressed into biomethane. The cooperative would then have to assess and compare the following options on a netback basis:

1. Inject renewable gas directly into the grid.
2. Sell gas as transport fuel to captive fleets or commercial fuel retailers.
3. Sell gas back to coop members to be used for heating and electricity.
4. Provide heat and/or electricity for local community.

It is not economically viable to transport most feedstocks (grass silage and slurry) over long distances[185] so plants must be in close proximity to supply. To ensure connection to the grid, AD plants can be built directly at the point of connection. Cooperative patronage would further encourage farmer buy-in, de-risking their participation, ensuring an economic bottom line and a return for the digestate produced.

The key role cooperatives play in rural social and economic development and the potential for adding to this through AD development should be additionally recognised in the next Common Agricultural Policy (CAP) and form part of Ireland's rural development strategy. Irish agricultural cooperatives can further increase the sustainability of Irish agriculture and the wider food industry through the development of AD plants. Within the Farm to Fork Strategy, the production of renewable energy through the development of AD is referenced as an important farm opportunity to reduce methane emissions[186]. These opportunities and the role cooperatives will play in bringing them to fruition should be prioritised in the future CAP.

Additionally, the development of this sector presents important opportunities for the Irish beef sector. The Irish beef sector is of great economic importance to the country, with a value of €6.92 billion in 2016 and exporting around 90% of total output[187]. However, the profitability of the sector is low, with only 13% of cattle rearing farms classified as economically viable and 43% as economically vulnerable in 2019[188]. Concurrently, in 2019 75% of Irish dairy farms were found to be viable, benefiting greatly from the purchasing power and organizational characteristics of dairy cooperatives. The Beef Plan Movement has recognised the opportunities associated with AD and has begun to explore the establishment of 50-60 farmer-led cooperatives to supply feedstocks for AD plants[189]. The development of beef cooperatives and the role of AD within them should be supported through the Ireland's rural development strategy and the future CAP.

What Improvements Can Government Make?

Renewable gas is critical to the stability of energy supply in a carbon neutral world. Unlike the intermittent wind and solar, Biomethane is a firm dispatchable resource which can guarantee a secure level of energy supply. It is clear that policy must robustly support the development of an anaerobic digestion sector of strength to facilitate this complementarity.

» Policy in Ireland does not adequately incentivise anaerobic digestion and renewable gas production, and there was no allocation of RESS funding to anaerobic digestion in 2020.

» A clear strategy for AD development through enhancing the focus on AD within the RESS scheme.

» A clear commitment to push the AD agenda should be supported in CAP negotiations.

» A strong statement of Government support for AD applications to the RESS

With a clear European bioeconomy agenda, looking towards the leaders in this field will offer better direction towards this transition. Within Ireland's policy context, AD and renewable gas generation are paired with wind and solar, both intermittent energy sources. Biomethane, however, is a firm dispatchable resource which can guarantee a secure level of energy supply. When considering the stability and versatile nature of the gas and the potential for cascading products, it offers significant value to stand alone from a funding perspective as is the case in several European countries. Additionally, renewable energy support schemes in Ireland favour electricity generation over gas, presenting an important policy gap. However, a projection by Baringa of Ireland's energy mix in 2050 reveals that gas will continue to play an essential role in Ireland's energy security. This paired with the 56 potential gas injection points reiterates the need for a sector specific scheme. The move to a carbon neutral electricity sector and the assurance of a stable energy supply will require support for renewable gas, including biomethane and hydrogen[190].

There is potential within the RESS scheme to broaden and enhance its focus on AD and the generation of biomethane, offering long-term contracts in the form of a premium on top of the market price. The stability and flexibility of the technology through the multiple products it generates justifies a proportion in RESS funding specifically directed towards AD projects. Potentially funded AD projects through the RESS scheme should aim to support cooperative-led initiatives along with developer, community and farm led projects.

To deliver commercial scale, large scale developers will need to come into the market, however, it is equally important that government policy facilitates local innovation wherever possible. Other funding options that stimulate indigenous IP and innovation should also be directed towards bioenergy development, such as the Climate Action Fund, funding under the EU Green Deal, Science Foundation Ireland, etc.

It is also important to introduce market pulls and incremental price inputs. For example, the price of carbon has remained resilient in the face of COVID-19. Anaerobic digestors contribute significantly to carbon reductions throughout multiple sectors. AD plants and developers should be rewarded for these contributions. These significant environmental contributions along with the potential socio-economic benefits AD development can bring should be further supported through CAP negotiations.

A wide-scale deployment of AD in Ireland will require price certainty for developers. This can be guaranteed through the following:

» A clear national strategy for AD, bioenergy and the bioeconomy.

» Supports, subsidy schemes and long-term contracts directed at AD and bioenergy development through the RESS scheme and other funding options.

» Market pulls as AD not only generates energy it also decarbonises participating sectors.

Can the Planning System be Improved?

» Streamlining the application, licensing, and grid connection processes is required.

» Clarity and precision throughout planning policy and from national to regional and local is needed.

In order to realise the full benefits of AD, further streamlining of planning and regulation is required[191]. The planning process to develop an AD plant requires a number of steps that cannot currently be undertaken in parallel.

Developers must first seek planning permission regarding the design of the plant. Once the design of the plant is granted consent, a second application to gain conditional approval is required validating that all operational procedures and HACCP are in order. Several issues developers face in this process have been identified by the Composting and Anaerobic Digestion Association of Ireland (Cré).

One of the main concerns regards the 5-year limit for construction from the date of approval of the first stage.[192]

Potential operators and developers must additionally seek out either a waste management facility permit from the local authority and/or an EPA licence, depending on feedstock choice. This cannot be done in parallel with the planning permission. The permit or license is granted once the authority *"deems that the application complies with the necessary regulations."*[193]

A third application must be made by potential developers to obtain grid connection approval. Planning permission and necessary licences are required in order to receive a connection. This process often takes longer then the previously obtained planning permissions last, resulting in significant delays for developers.

Further, there are significant variations in planning application assessment as a result of differing development plan objectives relating to AD among the various local authorities[194]. To boost investor confidence, clarity, precision and consistency is needed at each level of plan making from Ireland 2040 to the Regional, Spatial and Economic Strategies and county development plans.

Additional deterrents for potential AD developers include the process of judicial review and planning appeals. The Court of Appeals is under a major backlog resulting in a two year wait for hearings[195]. Often, objections and opposition campaigns against infrastructure projects are pursued up to the Supreme court, regardless of the legal arguments. There is precedent for EPA-licensed waste-to-energy plants being in "legal limbo" for over six years due to planning and legal appeals through An Bord Pleanála, the High Court and the Supreme Court[196].

Planning reform and streamlining, however, could help to increase energy generated from renewables significantly. The widescale development of AD across the nation will require the following from the planning system:

» A planning system that better caters to AD and biogas development/infrastructure.

» Alignment of environmental licensing, grid, and regulatory systems.

» Clarity, precision, and consistency from Ireland 2040 to the Regional, Spatial and Economic Strategies and county development plans.

» Review and reform of courts processes for AD planning cases.

Conclusion

In Ireland anaerobic digestion is already proven in many operational facilities. There is a great flexibility to the technology that can adapt to different feedstocks and blends, turning waste into energy and capital. In many ways it is the purest representation of what the circular bioeconomy has to offer.

The technology has been embedded at significant levels in multiple countries that have a supportive regulatory and fiscal environment. With a strong cooperative network and ethos in Ireland, and a planning and regulatory system that needs refinement rather than revolution, we are well placed, if not ideally and uniquely placed to capitalise on the potential of anaerobic digestion to provide a stable baseload of green energy.

The focus now must be on ensuring that the fiscal environment is encouraging, through increased RESS focus and by actively signalling intent to the market. As in every facet of energy generation, when the investor environment is facilitative, the market responds quickly. The RESS programme is nothing but positive, but it must support a diversity of technologies to truly ensure energy resilience that is green, sustainable and robust.

Appendix

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Project Stakeholders

Donal Kissane – Gas Network Ireland

Darragh Kyne – Gas Network Ireland

Kenneth McGrath – Ashleigh Environmental

Kieran Lettice – Energy Cork

Padraig Slyne – EirGrid

Ciaran Rabbitt - EirGrid

Daniel Keogh - EirGrid

Carol Power – UCC

Barry Caslin – Teagasc

John Mullins – Amarenco Group

Kenneth Long – Flogas

Tracey Breen – Ashgrove Renewables

Cormac Murphy – Ashgrove Renewables

Dave Austin – Tungsten Consulting

Nico O'Rourke – Bord Gais

Brian O'Shea – Bord Gais

Enda Buckley – Carbery

David Wall – MaREI

Richard O'Shea - MaREI

Chris O'Callaghan – Inver Energy

Daniel Fitzpatrick – Inver Energy

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Catherine Joyce O'Caollai – Indaver

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