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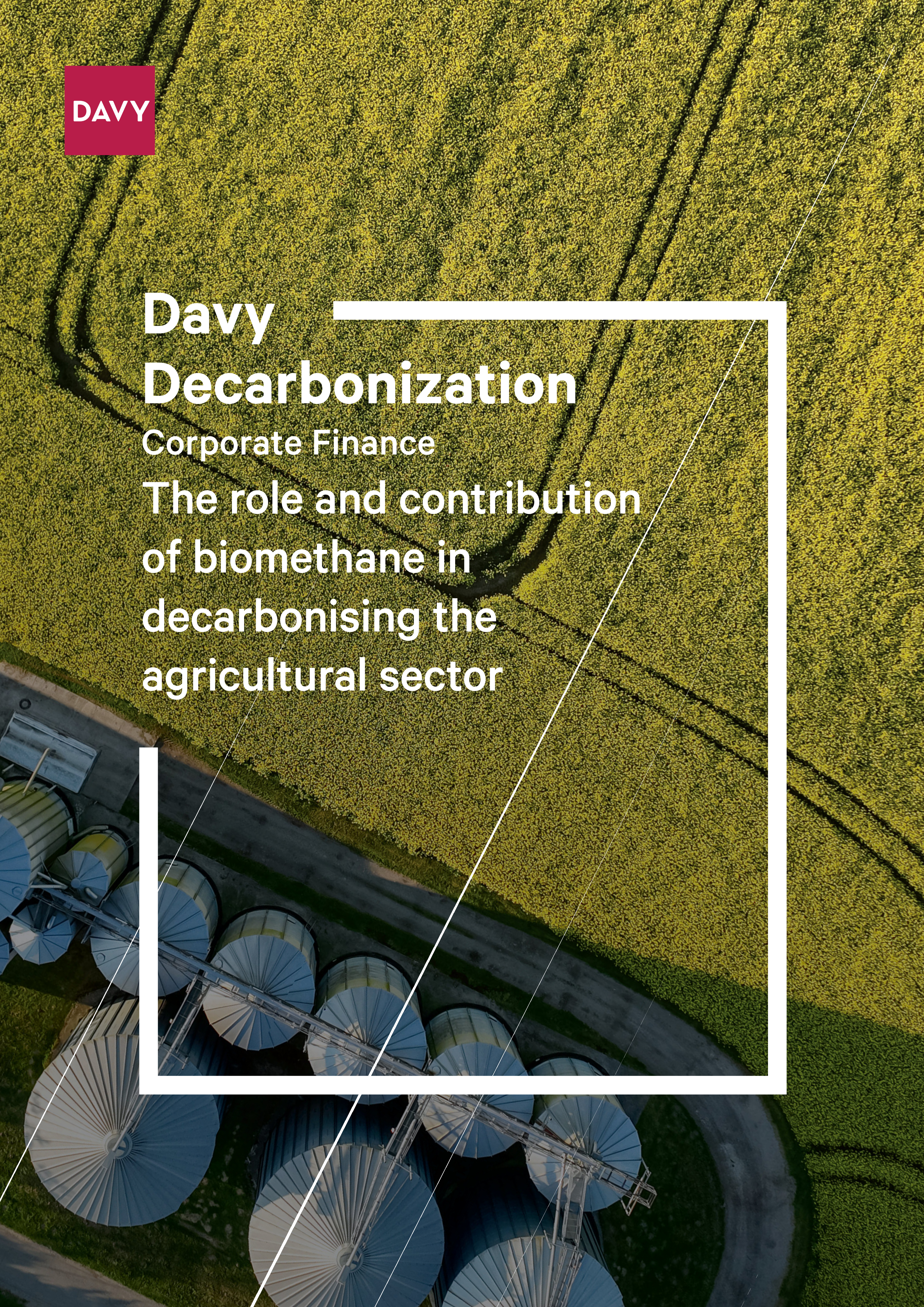

Davy Decarbonization

Corporate Finance

The role and contribution of biomethane in decarbonising the agricultural sector

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Key findings

Biomethane can play a dual role in decarbonising the agriculture sector - which accounted for over one-third of Ireland's Greenhouse Gas (GHG) emissions in 2021 - and also as a renewable fuel to decarbonise the gas grid. Decarbonised gas in turn can assist with providing a low-carbon solution for hard-to-abate sectors, for example those requiring high temperature industrial heat processes.

The production of biomethane through anaerobic digestion is a well understood process with an estimated 37 TWh produced in Europe in 2021. An EU target of 35 billion cubic meters has been set EU wide by 2030, which represent a growth of c. 8X. In Ireland a target of 5.7 TWh by 2030 has been set (with an intermediate target of 1 TWh by 2025) – with the national gas demand of 52 TWh (2023), the 2030 target represents a share of approximately 10%.

There are currently two facilities in production (75 GWh per annum) injecting biomethane into the Gas Networks Ireland's (GNI) gas grid and 43 biogas facilities (580 GWh) which are used for heat or electricity generation. A previous white paper by Davy Investing in Tomorrow: Shaping a Net-Zero Future estimated the investment requirement to be of the order of €1.6 billion by 2030; in the analysis below (assuming c. 100 smaller facilities (3.25 MW) and 30-35 larger facilities (10 MW)), we revise this to c. €1.5 billion.

This paper is concerned with biomethane (which will compete for the available national biomass supply) - there are various estimates of the biomethane resource available including: the National Heat Study (1.1-8.2 TWh); from Gas Networks Ireland (14.8 TWh); and from the Sustainable Energy Authority of Ireland (0.3-1.2 TWh).

A variety feedstocks are available, the main ones being: food waste or waste from food processing activities: animal slurry; waste water sludge, organic waste and grass silage. Our analysis suggests that organic food and industrial waste will only be able to support a small proportion of the 5.7 TWh target. The balance will have to come from a combination of grass silage and animal slurry.

Table 1. Feedstock required to reach Government target assuming

Feedstock	Energy potential (MWh)	Price (€/MWh)	Assumed cost € per tonne
Food waste	226	-100	-30
Milk processing waste	44	-78	-30
Slaughterhouse waste	57	-67	-30
Animal slurry	1997	45	5
Grass silage	3376	66	50
Total	5700	50	-

Source: SEAI, EPA, Teagasc, Davy estimates

The economics of producing biomethane from grass silage does not make economic sense if the biomethane can only be sold at the current natural gas price. It will therefore require some form of support. The level of support will depend on the size of the plants due to economies of scale as set out below.

Table 2.

	Plant scale (MW)	
	3.25	10.0
Estimated cost of production (€/MW)	91	80
Biomethane price required to drive 12.5% Return on Equity (c/KWh)	12.5	10.6
Assumed natural gas price (c/kWh)	3.5	3.5
Implied support (c/kWh)	9.0	7.1
Average Annual Cost to Government (€M) to Meet Target	512	404

Source: Davy estimates

Nonetheless, wider considerations may auger well for an arrangement that combines larger and smaller (community/farm-level) facilities including availability of the gas grid and the ability to install a larger scale upgrading facility and associated transport logistics.

Research by Teagasc indicates that the production of forage crops, with the capacity to produce high yields with low levels of Nitrogen fertilizer, such as red and white clover-based crops are best placed to meet the feedstock requirements for an anaerobic digestion industry. It points to using a grass clover sward mix (up to 30% clover even spreading) and to grow the crop without the use of chemical nitrogen and that 16 tonnes of dry matter per hectare per year is achievable within five years. Using the digestate from anaerobic digestion plants on farms allows even spreading of nutrients across and between farms which reduces nutrient load on individual farms/land areas and limits the risk and negative impact on water quality.

Introduction and policy backdrop

Biomethane can play a dual role in decarbonising the agriculture sector - which accounted for over one-third of Ireland's Greenhouse Gas (GHG) emissions in 2022 (38.4%) - and also as a renewable fuel to decarbonise the gas grid. Decarbonised gas in turn can assist with providing a low-carbon solution for some of the hard-to-abate sectors, for example those requiring high temperature industrial heat processes.

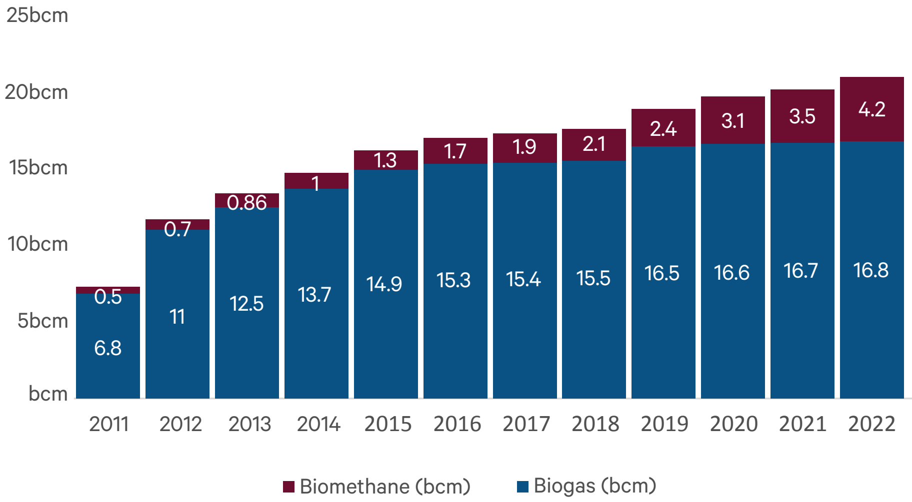
EU wide

The production of biomethane through anaerobic digestion (AD) is a well understood process with an estimated 37 TWh produced in Europe in 2021 and 44 TWh produced in 2022. Biomethane production in Europe doubled between 2018 and 2022, from 2.1 billion cubic meters (bcm) to 4.2 bcm and currently is c. 2% of natural gas demand.

Figure 1 shows the ramp up in biogas and biomethane production across Europe: the growth in biogas is slowing whereas biomethane production is increasing rapidly.

Europe has seen a shift from biogas production to upgrading to biomethane over time, particularly since 2011. Over the last 10 years Biogas production has grown at 4.3% and biomethane at 19.6%. We expect this trend to continue.

Fig 1. European Biogas and Biomethane Production:



Source: EBA statistical report 2023: Highlighting the Rapid Growth in European Biomethane Production bcm = Billion Cubic Metres

An EU target of 35 billion cubic meters has been set EU wide by 2030, which represents a growth of 8X. This target is estimated to require c. €37 billion in investment. The Davy estimate of this growth is shown in Table 3 under three scenarios: Base, Expected and Target.

Table 3. Davy view of the Scenarios of Growth European Biogas and Biomethane Production

	Annual Growth Rate Used	Basis of Growth Rate	2030 Production achieved
Case 1 (Base)	16%	6-year historic compound average growth rate	14.0 bcm
Case 2 (Expected)	21%	3-year historic compound average growth rate	18.7 bcm
Case 3 (Target Achieved)	30%	Required Rate to achieve target	35.3 bcm

Source: European Biogas Association statistical report 2023: Highlighting the Rapid Growth in European Biomethane Production

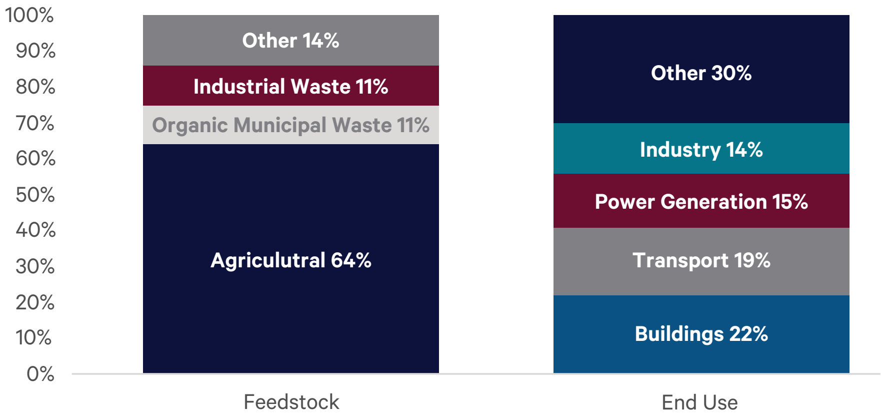
The bulk (85%) of the production is in Germany, France, Denmark, The Netherlands and the UK. Germany is the largest producer of biomethane, double that of the next largest producer (in 2021). Germany produced 34% of Europe's biomethane in 2021; UK 17%; Denmark 15%; France 12%; Italy and the Netherlands both 6% and the remaining 9% came from other European countries. Appendices 'A1' and 'A2' are case studies on Germany and Denmark.

There are approximately 1,300 biomethane plants across 24 European countries (c. 20,000 biogas plants) and 60% of the biomethane plants are connected to the gas distribution network. We estimate that an additional 5,000-9,000 biomethane plants (dependent on plant size between 30-65 GWh) will be needed to achieve the 2030 target.

At EU level, biomethane use is well diversified: power generation (15%); heating and cooling in buildings (22%); transport (19%); industry 14%; and other 30%. The balance is used miscellaneously in different countries. For example, Estonia, Finland and Italy use biomethane for transport, while the UK uses it c. 50% in buildings, 40% in power generation and 10% in industry. Feedstocks are approximately two thirds agricultural based and 11% organic municipal waste and 11% industrial waste. This is shown in Figure 3 below.

A trend is emerging where more countries are shifting from biogas subsidy schemes to biomethane subsidy schemes. The most common subsidies schemes are feed-in tariffs or feed-in premiums. Some more mature markets are relying on market-based systems.

Fig 2. EU feedstocks and end uses



Source: Ireland's Draft National Biomethane Strategy 2024, European Biogas Association 2023

Ireland

In Ireland a target of 5.7 TWh by 2030 has been set (with an intermediate target of 1 TWh by 2025) and the national gas demand in 2023 was 52,247 TWh and according the 2030 target represents a share of c. 10%. There are currently two facilities in production injecting biomethane into the Gas Networks Ireland's (GNI) gas grid which produce an estimated 75 GWh per annum. There are a further 43 facilities producing an estimated 580 GWh of biogas which is used for heat or electricity generation. Some of these plants could potentially be upgraded to produce biomethane.

Bioenergy more generally is well recognised as being capable of contributing to national targets for renewable energy sources (RES), energy security and to the circular economy. At the EU level, the Renewable Energy Directive (currently in its 3rd iteration, known as RED-III) sets mandatory overall EU targets for renewable energy of 42.5% by 2030. This is to be met by way of various targets (with certain options, sub-targets, and limits) for wind, solar, renewable energy in transport[1], advanced biofuels, renewable fuels of nonbiological origin and from waste oils and food and feed-based biofuels.

The plan for Ireland is set out in the (updated draft) National Climate and Energy Plan (well summarised in Table 4 of that plan) which sets out trajectories for Ireland to reach an overall RES target of 31.4% by 2030 and for example comprises a target of 68% renewable electricity (known as RES-E for which an updated 80% target has now been set), 15% renewable transport (known RES-T) and 23% renewable heat (RES-H). We understand that an updated NECP is in preparation.

Extract 1: sets out the trajectories for renewable energy for various years to 2050

Renewable Trajectories	2018	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2040	2050
RES-H&C (%)	6.4%	6.3%	5.1%	6.3%	11.8%	12.8%	14.6%	16.4%	17.7%	19.1%	20.7%	22.9%	38.6%	40.6%
RES-E (%)	33.3%	39.1%	36.4%	36.8%	39.2%	41.0%	41.7%	44.7%	47.0%	51.0%	57.7%	67.7%	80.1%	82.6%
RES-T (%)	7.2%	10.2%	4.4%	5.5%	5.3%	6.0%	6.8%	7.9%	9.2%	10.8%	12.6%	14.9%	52.5%	70.4%
Overall RES Share (%)	10.9%	16.26%	12.5%	13.1%	16.8%	18.1%	19.4%	21.1%	22.5%	24.3%	27.2%	31.4%	46.2%	51.1%
Article 4(a)(2) Target for RES Increase	_	_	_	18.0%	_	_	43.0%	_	65.0%	_	_	100%	_	
RES Min Trajectory (%)	_	16.0%	_	19.3%	_	_	23.8%	_	27.8%	_	_	34.1%	_	
RES Projected Trajectory (%)	_	16.26%	_	13.1%	_	_	19.4%	_	22.5%	_	_	31.4%	_	
Shortfall (%)	_	_	_	6.2%	_	_	4.4%	_	5.3%	_	_	2.7%	_	

Source: Taken from the (updated draft) National Climate and Energy Plan (WEM means with additional measures i.e., measures not currently in train but under consideration).

1 RED-III changed the architecture of the targets (from RED-I and RED-II) by introducing an option for Member States to choose between a target for **renewable energy in transport** or a target for **reduction in greenhouse gas emissions.**

Elsewhere, the EU has set mandatory targets for:

- The production of biomethane (35 billion cubic meters by 2030) as set out in REPowerEU (and accompanying communication to accelerate biomethane) representing an increase of approximately 8X at an estimated cost of €37 billion.
- For the use of Sustainable Aviation Fuels (2% by 2025; 63% by 2050 and a sub-target for renewable fuels of non-biological origin) and the introduction of synthetic aviation fuels (post 2030) as set out in ReFuelEU Aviation[2]; and
- A reduction of greenhouse gasses intensity of fuels used onboard ships (2%/2025 moving to 80%/2050) and sets out onshore power requirement as set out in ReFuelEU Maritime targets[3].

The production of biomass is a significant means of addressing these targets, but any production must meet the sustainability criteria set out in the RED, which addresses inter alia management of land and the use of land for food production. **Accordingly, the available capacity to produce biomass in Ireland must carefully balance all these considerations:**

- The RES-E target (80% by 2030 target has been set) is to be met by using biomass in power plants (e.g., Bord na Mona's Edenderry power plant), along with other renewable sources such as wind, solar, hydro, tidal etc.
- The **RES-T target** will be met by mandating the use of Renewable Transport Fuels **(RTF)** by way of the **Renewable Transport Fuel Obligation**[4] (currently being B20 diesel, E10 petrol and advanced biofuels target of 5.5%[5] by 2030) along with electrification of transport (which will be increasingly reckoned as renewable as RES-E trajectories increase).

  In passing, it is worth noting the composition of Ireland's biodiesel fuel stock is unusual compared to EU norms having very low reliance on crop-based feedstocks and very high reliance on used cooking oil and tallow derived). This is set out in the roadmap to achieve 14% RES-T (which then addressed a requirement of RED-II) set out in *A Review of Requirements and Constraints on Biofuels in Ireland Arising from RED II and National Targets* prepared for Department of Transport and the National Oil Reserves Agency.

  Biomass and biogas will also contribute to the RES-H target and a **Renewable Heat Obligation (RHO)** is being developed to encourage the uptake of renewables (including biomethane discussed below) in this sector. A national biomethane strategy has also been published.

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2 There are several techniques to reduce emissions from aviation including new engine technologies, new wing designs, avoiding tankering, use of (electric) jockeying and flying in atmospheric zones where contrails are less potent. Nevertheless, approximately 2/3rd of the abatement effort is expected to be achieved from sustainable aviation fuels.

3 Bulk marine transport of fossil fuels (oil, gas, coal) is set to decline over the coming decades and this 'demand reduction' will naturally lead to lower emissions from the sector. Electricity is widely predicted to take over in the inland waterways/near shore uses and have a strong contribution to make to larger vessels who can cut emissions, pollutants, and noise on approach or in ports. The industry is experimenting with other fuels (in some cases tri fuels), but biofuels and batteries widely agreed as the future.

4 The new name for the former Biofuels Obligation Scheme.

5 RED-III has mandated a 5.5% combination of Advanced Biofuels (Annex IX, part A) and Renewable Fuels of nonbiological origin which must be 1% at a minimum.

- The RED iterations build on an earlier system of **Guarantees of Origin** intended to assure customers that energy they sourced came from renewable sources, which was implemented over time in Ireland by S.I. No. 483/2014 and S.I. No. 147 of 2011 and presently administered by NORA.

RED-III (Recital 9) extended the Guarantees of Origin scheme to include biomethane and GNI were appointed the authority by S.I. No. 350/2022. This has proven useful to Electroroute who ship biomethane from continental Europe to Ireland to assist decarbonisation of the DHL fleet and the EU statistics agency ruling that this reckons to Ireland. Each certificate guarantees that the biomethane is produced and independently verified to this RED standard and that the equivalent amount of biomethane has been injected into the gas network.

Biomethane Importation

ElectroRoute, an independent power and gas trading, services and supply business headquartered in Dublin and wholly owned by Mitsubishi Corporation, was the first operator on the island to import and certify biomethane from Europe into Ireland for use in the renewable fuel transportation obligation. This has enabled the use of biomethane from multiple sources in advance of a liquid biomethane market on the island of Ireland.

Having worked closely with industry partners and regulatory authorities in confirming the evidentiary requirements, ElectroRoute has established Renewable Transport Fuel Certificates (RTFCs) on foot of this importation, a first for biomethane in Ireland.
In doing so, ElectroRoute is providing cross border gas shipping through Europe and mass balancing services to ensure that the importation of biomethane is in line with RED conditions. This process includes engagement with upstream and downstream parties to ensure voluntary certification is in place and to ensure the relevant proof of gas capacity, gas nominations and mass balancing evidence relating to the source and carbon intensity scores for the fuel. Ultimately, all of this information is utilised to in an independent audit process to evidence the sustainability credentials of the procured biomethane.

The importation of biomethane in an interim step prior to a deep and liquid biomethane sector in Ireland and provides energy users with an opportunity to decarbonise their activities sooner, whilst also gaining crucial insight into the operating characteristics for their sites.

Overall, there is competition for the use of bioenergy in Ireland and the total projected demand is set out in the NCEP *(ibid)* (Table 6 of that Plan across sectors Electricity, Heat and Transport over the time horizon to 2050.

Extract 2: Bioenergy demand (WEM) - summarises the bioenergy demand forecast to be used in each sector up to 2050

Bioenergy Demand, Total Final Consumption (ktoe)	2018	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2040	2050
Electricity													
Solid Biomass	29	40	44	59	88	88	88	87	87	87	86	12	12
Biogas	1	3	3	3	3	3	3	3	3	3	3	3	3
Landfill Gas	12	10	9	6	6	6	6	6	6	6	5	4	4
Renewable Waste	21	30	30	28	29	28	28	29	28	28	25	21	20
Heat													
Solid Biomass	242	224	236	352	384	426	461	472	483	503	550	1039	1001
Biogas	10	12	13	10	10	10	10	10	10	10	10	10	10
Transport													
Ethanol	27	20	23	39	44	49	48	47	46	45	44	19	3
Biodiesel	127	151	177	276	308	340	338	336	332	328	323	234	164

Source: National Climate and Energy Plan (WEM - with additional measures).

This paper is concerned with biomethane (which will compete for the available national biomass supply) and as set out above, for which a national target of 5.7 TWh (or 10% of the gas demand) has now been set. Domestically, in addition to the RHO, a National Biomethane Strategy has also been published. A significant variable in the draft strategy was whether and what form (financial) supports will be put in place, and in the now published strategy grants have been favoured to an initial amount of €40 million.

There are various estimates of the biomethane resource available including:

- The *National Heat Study* (2020) – estimate 1.1-8.2 TWh;
- GNI (2023) 14.8 TWh – this is taken from the *Biomethane Energy Report* which complied a data set and interestingly Figure 3.4 of that report breaks the potential down county by county with Co. Kildare with the highest density (1,491 MWh/km2) followed by Monaghan, Cavan and Limerick; and
- SEAI (2017) 0.3-1.2 TWh (4.6-21.9 PJ).

Renewable Heat Obligation Scheme – Under consultation the summary below is taken from the various Government consultations to date.

It is expected that the scheme will place an obligation on the suppliers of fuel that is used for heating to ensure a certain proportion of that fuel is renewable.

- The obligation will cover suppliers of all fuels supplied in the heat sector (oil, LPG, natural gas, coal, etc). Electricity supplied for heat will not be subject to the obligation.
- It envisaged that a Heat Obligation Rate will be set each year which is effectively the proportion of energy supplied that is from renewable sources. It has been signaled that an introductory rate of 2% would apply for a 3-year period ramping up thereafter to 10% by 2030.District heating systems using waste heat/ renewable heat would not be subject to the obligation.
- The penalty for non-compliance therefore must be higher than the cost of the renewable fuel.
- The theory is that the lowest cost renewable fuel i.e., biomethane will be the first to be adopted.

Technology and process

Anaerobic digestion is the conversion of organic material by microorganisms in the absence of oxygen into biogas and digestate. There are four stages in the process: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Each stage breaks down different parts of the material. The AD tank is completely sealed with less than 0.5% oxygen in the headspace and is typically maintained at a mesophilic temperature of 37-42°C.

Biogas is a mix of methane (50-65%), carbon dioxide (CO2) (35-50%) and a small proportion of other gases. It can be used to supply heat and/or to generate electricity for example in a local combined heat and power **(CHP)** plant. One cubic metre (M3) of biogas contains c. 23 million joules (MJ) of energy which can generate 4-6 kWh of heat or 2.2 kWh of electricity.

Biogas can be upgraded to biomethane which is a near-pure source of methane in a process that removes CO2 and other gases and is now classified as "biogenic CO2". Biomethane can be injected directly into the gas grid to replace natural gas. The cost of producing biomethane is estimated at below and is well above the current price of natural gas (c. 3c/kWh) making the substitution difficult to justify on economics alone.

BioCNG is compressed biomethane at a pressure of 20-25 MPa. It is very similar to regular **Compressed Natural Gas** in terms of fuel properties, economy, engine performance and emissions.

Feedstocks

A variety of biodegradable biomass raw materials (or feedstocks) can be used to produce biogas through the AD process, the main ones being:

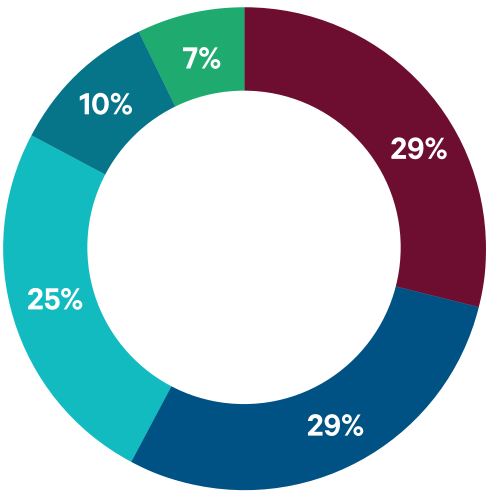
- Food waste or waste from food processing activities
- Other organic waste from industrial processes
- Wastewater treatment plant sludge
- Animal slurry and manures
- Grass silage from agricultural crops including grass and other energy crops or the residue from other crops including cereals, energy crops (sugar beet and cane) and protein crops such as soyabeans and rapeseed.

Other feedstocks include organic industrial waste and the organic component of municipal waste and sewage sludge. The availability of these various raw materials combined with the energy content of each will determine the potential energy which can be delivered through AD. In this section we examine each feedstock and how it could contribute to the overall target.

Food waste

A total of 753,000 tonnes of food and industrial waste was generated in Ireland in 2021 according to the latest data from the Environmental Protection Agency **(EPA)**. Of this, almost 30% was produced by households with a similar volume from the food processing sector – predominantly slaughterhouse waste **(SHW)** and milk processing waste **(MPW)**. One-quarter was generated by the Restaurant and Food Service sector.

Chart 1 – Food Waste in Ireland 2021



Households **Manufacturing & Processing** **Restaurant & Food Service**

Retail & Distribution **Primary Processing**

Source: EPA

Almost 80% (590,000 tonnes) of this was reused either in composting (49%) or AD (51%) due to the high level of contamination in food waste generally. This implies just over 300,000 tonnes going into the AD sector.

The potential for biomethane production from food waste is **relatively limited in Ireland**. Based on the EPA estimates, the current volume of waste allocated to AD would generate c. 90MWh of electrical power or approximately 225 GWh of biomethane. Even assuming the full volume of food waste were processed through AD would still only generate 600MWh.

Nevertheless, food waste is a very attractive feedstock from an economic perspective where plants using this feedstock generally receive a gate fee to process the waste. Businesses like Green Generation in Co Kildare are presently the main processors of food waste through AD while much of the rest is currently transported to AD in Northern Ireland.

Animal slurry

The cattle herd in Ireland declined slightly in 2022 to just over 6.5m head according to latest data from The Department of Agriculture, Food & Marine **(DAFM)**. Assuming an average 4.6 tonnes of slurry from each animal per annum implies total slurry production of c. 31 million tonnes. This type of slurry typically has a low dry matter **(DM)** content of 7% which will limit is usage, particularly in conjunction with grass silage. Assuming an energy content of 108-150kWh per tonne (circa 1.6MWh per tonne of DM) implies total energy potential of almost 3400GWh (3.4TWh).

Table 4. Availability of animal slurry in Ireland and potential for biomethane production via Anaerobic Digestion

Animal Slurry	Cattle	Pigs	Total
Herd size in Ireland (000)	6505	1640	8145
Tonnes of slurry per animal per year)	4.6	3.3	
Total slurry produced (000 tonnes)	30171	5412	35583
Energy content (kWh/ tonne)	113	107	
Total energy potential (GWh)	3396	579	3975

Source: DAFM, EPA, On-line PhD Thesis, Davy estimates

The pig herd and was just over 1.64 million in 2022. Assuming 3.3 tonnes of slurry per animal with an energy content of circa 60-130kWh per tonne (depending on the length of time the slurry is stored) implies potential energy generation of 324-686 GWh per annum.

Combined therefore, animal slurry has the potential to generate almost 4.0 TWh of energy and summarized in Table 4. Slurry on its own however is not a suitable material for the AD process given the relatively low yield per tonne. It works best when mixed with another material like food waste or grass silage.

An emerging approach is to separate the slurry on site at farms and transport the (30% DM) solid fraction to centralised AD plants. This approach has several potential benefits. The separation process removes approximately 12% of the total volume, and the resulting solid fraction has a typical energy content of over 600 kWh per ton. If the entire national slurry volume was separated and the solids sent for AD it would equate to approximately 4.3 million tons of material with energy content of circa 700 kWh per tonne, totalling 3.1 TWh.

Grass silage

One of the biggest opportunities for the development of the AD sector in Ireland is through the use of grass silage as a feedstock. Not only will this provide an adequate level of raw material, it will also provide a new and therefore diversified potential income stream for farmers which could prove more stable than current existing enterprises such as suckler cows or sheep. Grass silage is also one of the few raw materials which can be supplied in such quantities as to satisfy the 2030 Government target of generating 5.7 TWh of biomethane from AD.

According to the SEAI's National Heat Study, there are c. 4.1m hectares (ha) of land farmed as pasture in Ireland currently. Assuming a stable herd with no significant productivity improving initiatives, it is estimated that 150,000 ha could be used for growing grass for AD plants – without impacting other food production. Assuming a utilisation/take-up rate of 42% implies 67,000 ha of land which has the potential to generate 2.6 TWh of power as detailed in Table 5. This represents just 1.6% of the current pastureland bank.

Table 5. Potential for energy generation using grass silage as AD feedstock

Total pastureland farmed in Ireland (000 ha)	4100
Area of land potentially released for AD (000 ha)	159
Utilization rate	42%
Land used for AD (000 ha)	67
Tonnes of FM grass silage per ha per year	52
Total tonnes FM grass silage (000)	3484
DM percentage	25%
Total tonnes of DM (000)	871
Energy content (MWh/ tonne)	3.03
Total energy potential GWh	2639

Source: SEAI, Teagasc, EPA, Davy estimates

Grass silage on its own is not a suitable feedstock for AD – but when mixed with animal slurry could be significantly more effective. To satisfy RED requirements, the ratio of grass silage to slurry (on a fresh matter – FM) basis can vary from 1 grass to 2.4 tonnes of slurry up to 1 tonne of grass to 5.4 tonnes of slurry. Using grass silage as the weight determining variable and a ratio of 1 tonnes of grass to an average 4 tonnes of slurry, Table 6 illustrates the potential energy generation from AD using this mix.

Table 6. Potential energy generation from grass/ slurry mix based on current land availability estimates

Potential energy generation from 1:4 grass/ slurry mix

	Tonnes (000) (fresh matter)	DM (%)	DM Tonnes (000)	Energy content per DM tonne (MWh)	Total energy potential (GWh)
Grass silage	3484	25%	871	3.03	2639
Cattle slurry	13936	7%	976	1.6	1561
Total	17420	-	-	-	4200
Land use (percent of total pastureland farmed)	-	-	1.6%	-	-

Source: SEAI, Teagasc, EPA, Davy estimates

Table 7 illustrates the amount of land required to produce sufficient grass silage which along with an equivalent amount of slurry would be sufficient to meet the government's 2030 target. This represents c. 2.2% of the current pastureland farmed.

Table 7. Pastureland required to meet Government 2030 biomethane targets

Volumes required to meet Government target 5.7TWh

	Tonnes (000) (fresh matter)	DM (%)	DM Tonnes (000)	Energy content per tonne (MWh)	Total energy potential (GWh)
Grass silage	4728	25%	1182	3.03	3582
Cattle slurry	18913	7%	1324	1.6	2118
Total	23642	-	-	-	5700
Land use (percent of total pastureland farmed)	-	2.2%	-	-	-

Source: SEAI, Teagasc, EPA, Davy estimates

The economics of biogas and biomethane production is highly dependent on the cost of the feedstock used. This is a function of both the energy content (and digestibility) of the feedstock as well as the cost. Producers may receive a gate fee for food or industrial waste while agricultural crops including grass silage may have to be paid for. Food/industrial waste and animal slurry are currently the most common feedstocks used but the availability of these will not be sufficient to meet the Government targets. **The big opportunity in the Irish market is for the use of grass silage as a feedstock**.

Table 8 illustrates the volume of each of the feedstocks described above required to meet the Government's 2030 target of 5.7 GWh of biomethane - and the relative cost of each. While organic food and industrial waste materials are the most attractive in terms of cost, the level of availability is not sufficient to achieve the Government's target. This can only be achieved by using a combination of grass silage and animal slurry.

In our analysis, we assume a cost of €50/tonne for grass silage and €5/tonne for slurry including the transport costs to deliver to the AD plant and potentially some cost if the slurry has to be pasteurized.

Table 8. Feedstock to meet Government target of 5.7 TWh biomethane production by 2030

Feedstock required to reach Government target assuming 1:4 grass/ slurry mix

Feedstock	Energy potential (MWh)	Price (€/MWh)	Assumed cost € per tonne
Food waste	226	-100	-30
Milk processing waste	44	-78	-30
Slaughterhouse waste	57	-67	-30
Animal slurry	1997	45	5
Grass silage	3376	66	50
Total	5700	50	-

Source: SEAI, EPA, Teagasc, Davy estimates

Assuming the maximum amount of food and industrial waste is used and that a 1:4 mix of grass silage and slurry (by fresh weight) is used to achieve the 5700GWh target, then almost 3400GWh will need to be derived from grass silage. Assuming a yield of 52 tonnes of FM silage per hectare implies just over 2% of the current land used for pasture will need to be allocated to growing gas for biomethane production.

Economics of biogas and biomethane production

A previous white paper by Davy *Investing in Tomorrow: Shaping a Net-Zero* Future estimated that the development of the AD sector in Ireland would require significant investment of the order of €1.6 billion by 2030 (to meet the 5.7 TWh target).

This investment will be funded by a mix of debt and equity and naturally to be viable an adequate a return-on-capital must be generated within the sector. Accordingly, we have built a financial model and assumed a top-level return on equity of between 10-15% will be necessary.

There are a number of factors driving the economics of AD including:

- The **type of feedstock**. Plants which receive a gate fee for feedstock (e.g., food or industrial waste) will naturally have an advantage. From above, **grass silage** and **slurry** will likely be the main feedstocks used. Our economic analysis (below) is therefore primarily based on this material.

- The **capacity** of the plant where larger facilities will benefit from economies of scale. In the analysis below, we compare the economics of a 3.25MW plant (typical scale assumed under the Climate Action Plan) with a larger 10MW facility each using the same feedstocks (grass and slurry).

- The **level of processing** of the gas i.e., specifically comparing using biogas used directly to generate electricity in a conventional CHP plant with an alternative of upgrading that same biogas to biomethane and injected into the gas grid with the captured and sale of biogenic carbon dioxide for example for the purpose of combining with Hydrogen to produce Sustainable Aviation Fuel.

Assumptions

The following assumptions underpin this analysis:

- The feedstock is assumed to be a 1:4 mix of grass silage at a cost of €50/ tonne and cattle slurry at a cost of €5/tonne (delivered and pasteurized) with the characteristics of the feedstock as set out in Table 6.

Table 9. Energy and cost metrics of grass and slurry as feedstocks for AD plants

Grass silage metrics		Cattle slurry metrics	
Tonnes per ha (FM)	52	Tonnes per animal	4.6
DM (%)	25%	DM (%)	7%
Biogas M3 per tonne DM	550	Biogas M3 per tonne DM	286
Biomethane content	55%	Biomethane content	55%
CO2 content of biogas	43%	CO2 content of biogas	43%
M3 Biomethane per tonne DM	303	M3 Biomethane per tonne DM	157
Energy content per tonne DM (MWh)	3.09	Energy content per tonne DM (MWh)	1.6
CO2 Kg/ M3 biogas	1.8	CO2 Kg/ M3 biogas	1.8

Source: SEAI, Teagasc, EPA, Davy estimates

- All plants are assumed to operate at 90% capacity utilization and have a useful life of 20 years.

- Digestate is returned to farmers at a net cost after processing of zero. Over time, it is possible that this material could be sold at a profit.

- Over time, captured biogenic carbon dioxide could be sold at a net positive gain to the AD plant. For now, we believe it is too expensive to capture and there is not a sufficient market for this material.

- The average natural gas price is 3.5c/kWh.

- Construction costs for biomethane plants (biogas facilities plus the upgrading equipment required for biomethane production) is €2m/MW for the larger (10MW) plants and €2.6m/MW for the smaller (3.25MW) plants. This latter figure is conservative and approaching the limits for small plants.

- Biomethane plants are funded using a 50/50 mix of debt and equity. The cost of debt is assumed at 6%. We back calculate the implied biomethane price (per kWh) which would result in a 10-15% return on equity with the quantum of Government support being the 'balancing figure'.

Analysis

In the table below, we compare the economics of a 10MW facility with that of a 3.25MW plant.

Table 10. Economics of varying scale AD plants

	Plant scale (MW)	
	3.25	10.0
Estimated cost of production (€/MW)	91	80
Biomethane price required to drive 12.5% Return on Equity (c/ KWh)	12.5	10.6
Assumed natural gas price (c/kWh)	3.5	3.5
Implied support (c/kWh)	9.0	7.1
Average annual cost to Government (€M) to meet target	512	404

Source: Davy estimates

We estimate the cost of production in a 10MW plant to be €80/MWh compared to €91/MWh for the smaller plant and correspondingly the smaller plant would need a biomethane price of 12.5c/kWh versus 10.6 c/kWh for the larger plant.

It can be readily seen that the development of a network of larger scale plants would therefore be more economical. This assumes a natural gas price of 3.5c/kWh (implying a 7.1c/kWh subsidy for the larger plants compared to 9.0c/kWh for the smaller facilities). Applying this to the government target of 5.7TWh results in an annual exchequer cost of €512 million per annum for a network of smaller plants, well above the €404 million per annum required to support a network of larger plants. This simply reflects the underlying economies of scale.

It is worth noting in passing that some operators may be able to negotiate attractive corporate Power Purchase Agreements (to support the investment case), this is unlikely to be sufficient to support the development of a sector to meet the scale of the 2030 government targets.

Biogas production

While it is clear that the underlying economies of scale favour larger plants (our analysis 10 MW plants for example), there may be other considerations (e.g., availability of the gas grid, localism or community participation) which could auger for a mixed configuration of plants, some larger and some smaller.

There are many conceivable configurations and networks of plant and for illustration, the following are interesting.

- A (network) of 10MW and 3.25 MW biogas plants each with an upgrader producing biomethane which is directly injected to the gas grid
- A network of smaller plants with upgraders with the biomethane being transported to a direct injection site.
- A network of individual standalone 3.25 MW biogas plants associated with a local heat/ electricity host (much like the current network in existence). This would not contribute to the biomethane target by definition (nor have biogenic CO_2 available for sale).

Our preliminary analysis suggests that the most likely outcome is a network of larger and smaller plants with the larger plants located close to direct injection sites and where the biomethane produced from the smaller facilities is transported to these direct injection sites.

On-farm economics of growing grass silage for anaerobic digestion

Many countries in Europe have developed successful AD industries with a variety of Agri feedstocks. For example, in Germany and the UK, maize traditionally was a commonly used crop grown as a feedstock (although being progressively phased out under RED).

In order for Biomethane to contribute to emissions reduction target for agriculture, it must be environmentally sustainable although it is scored against the energy targets. Amongst other things, this means that the energy used in the production of crops used for feedstock for AD plants must be clearly accounted. In particular, if chemical nitrogen is used to grow the crop for an AD plant, or if there is land use change, it will reduce the environmental sustainability aspect of the biomethane.

Teagasc is investigating the use of **red-clover** silage and **multi species swards** as feedstocks for AD plants. Ireland is unique across Europe in being able to produce high yields of grass silage, and the use of legumes such as clover would reduce or eliminate the requirement for nitrogen fertiliser.

Research by Teagasc has indicated that there is substantial scope to increase the availability of forage from Irish livestock farms in excess of livestock requirements by improving grazing management practices. For example, beef farms typically utilize approximately 6 tonnes of grass DM per hectare which is far below (being on poorer quality land) that being achieved by the top performing demonstration farms where grass utilization typically exceeds 10 tonnes DM per hectare.

In a scenario where grassland management and utilization practices improve, the CAP targets could be met with little livestock displacement. Importantly however, increasing the availability of forage should not be achieved by increasing the application of nitrogen fertilizer due to the impact on GHG offsetting and forage production costs. Also, use of chemical nitrogen to grow biomass for AD plants would make it difficult to achieve the RED sustainability criteria.

Current research by Teagasc indicates that the production of forage crops with the capacity to produce high yields with low levels of nitrogen fertilizer, such as **red and white clover-based crops** are best placed to meet the feedstock requirements for an AD industry. Furthermore, improving grasslands to support a biomethane industry must be balanced with the national biodiversity strategy which aims to conserve biodiversity in the wider countryside through the enhancement of high nature value farmlands.

Grass silage as a feedstock

The research points to using a **grass clover mix** (up to 30% clover) and to grow the crop without the use of chemical Nitrogen. The model would use a 1:4 (fresh weight) grass silage/slurry mix. Approx 40% of the digestate from the AD plant would be used on the silage crop and PandK (phosphorus and potassium) fertiliser would balance the off takes.

The FLEET (Farm Level Economic, Environmental and Transport Modelling of AD) project in Teagasc is currently investigating the economic and environmental benefits for farmers from supplying feedstocks and using digestate as a fertiliser on farm. The project is funded by SEAI, and part funded by Gas Networks Ireland.

Economic modelling suggests that a minimum price of €35-40/tonne (2018-2020 data) would be required to make it economically viable for a livestock farmer to consider switching (risk/reward) to supply an AD plant with grass silage. We have assumed a delivered cost of €50/ tonne in our analysis above. The initial research shows that the greatest economic benefit is for **cattle and sheep farmers** (receiving >€35/tonne) while for **tillage and dairy farmers** it does not give a significant economic return at <€40/tonne to make switching to supply AD plants viable.

Other benefits

Using digestate from AD plants on farms allows even spreading of nutrients across and between farms which reduces nutrient load on individual farms/land areas and limits the risk and negative impact on water quality. However, a key aspect of using slurry in AD plants is the requirement to have a steady flow of feedstock (slurry loses its gas potential over time). This will need investment in increased storage capacity and mechanisms for minimising gaseous emissions during slurry storage, alongside investment in silage clamps on farm.

The use of grass resources for AD has a distinct advantage from a farm diversification perspective in that it is a familiar practice for livestock and crop farmers. In this context, the willingness to adopt land use change is being assessed by an SEAI-funded FLEET project led by Teagasc, which is identifying farm scale, landscape level and national level economic and environmental implications of farm supplied alternative feedstock for AD at a regional level.

Clearly, the financial returns to the farmer will have an important bearing on the acceptability of producing grass for AD. The traded value for grass silage can be used as a guide for this diversification option; however, an additional premium is likely necessary, the extent of which being influenced by individual farmer's commitment to their existing enterprise and prevailing attitude to innovation and change. Collaboration will be key across farm sectors and industry. Investment will also be required in Knowledge transfer and education in growing silage for AD plants. Silage based feedstock would also benefit rural employment: increase in farm contractors (silage/slurry) etc.

Operator profiles

In the following we provide a brief profile of a selection of operators.

Green Generation

Green Generation operates a 3.5MW AD plant in Nurney, Co Kildare. The plant is owned and operated by **Billy Costello** a veteran of the AD industry in Ireland. In 2021, it received a significant investment from **Clonbio Ltd**, an Irish-owned operator of biofuel assets in Eastern Europe.

- Output: Until recently, the company generated electricity from biogas with the associated heat used to maintain the temperature of the digester tanks as well as providing heat for the co-located pig farm. In 2020, the company commissioned the first direct grid entry unit (Biomethane Network entry Facility – BNEF) for injection of biomethane into the gas grid and transitioned from CHP-only to biomethane (plus CHP for parasitic load). It uses a "virtual pipeline" whereby biomethane is transported in tankers under high pressure (250 bar) to the BNEF at Cush in Co Kildare about 6km from the AD plant. Digestate is provided to local farmers at zero cost.

- Feedstock for the plant is a combination of food waste from a number of retailers and factories as well as food processing wastes and pig slurry from the adjacent pig farm.

- Green Generation has a co-located sister company called **Paltech** which processes the plastic packaging associated with the food waste. This material is used to manufacture electricity pylons and motorway barriers.

Glenmore Generation Limited

Glenmore Generation Ltd (GGL) is owned by **Glenmore Farm Group**, which itself is owned and operated by the McElhinny family in Co Donegal. The company operates a 4MW AD facility.

- Output: As with Green Generation, up to 2020, GGL produced biogas which was used to generate electricity in a conventional CHP plant. Capacity of the plant was expended in 2021 and an upgrading facility was added which supported the generation of biomethane. This product is compressed in tankers and transported by road to Cush in Co Kildare where it is injected directly into the gas grid. The facility also generates circa 60,000 tonnes of digestate which is used as a source of fertilizer for the wider Glenmore Farm Group.

- Feedstock. The plant has capacity to use up to 90,000 tonnes of raw material from food and agriculture waste. Currently, the primary feedstocks are circa 25,000 tonnes of grass silage and 15,000 tonnes of chicken litter, as well as food processing residues.

Huntstown Bioenergy Limited

Sretaw, the family office of entrepreneur Eamon Waters acquired a 4.8 MW AD plant from **Energia** in North County Dublin in 2023. The plant was originally constructed by Energia in 2018 as part of the Huntstown energy complex and (partially) commissioned in 2019. It is expected to be operational under the new ownership structure in 2024.

- Output. The facility has been designed to produce biogas which is put through a CHP plant to generate electricity with the heat used in the AD plant itself. An upgrader will be installed in 2025 which will allow the production of biomethane which can be injected directly into the gas grid.
- The plant will also produce 90k tonnes of digestate rich in nitrogen, phosphorus and potassium. While this product is a valuable source of organic fertilizer, it is likely to be given away for free at least initially to local farmers. Over time, the digestate could be dried and pelletized and sold as an additional source of revenue. It is likely however that the price achieved for this product will just cover the associated processing costs.
- Feedstock: The plant will use a variety of feedstocks including food waste, food processing waste, slaughterhouse waste (SHW), and chicken litter. It is envisaged that the Huntstown plant will receive a gate fee for some of this feedstock with others covering the cost of haulage at a minimum.

Ormonde Organics Limited

Ormonde Organics Ltd (OOL) is a sewage sludge management company that has been operating since 2007. The 2MW plant located in County Waterford increased its capacity in 2021 and can now accept and process up to 80,000 tonnes of biological waste annually. This includes sewage sludge as well as food and animal by-products.

- Output: The 2MW plant generates biogas which is used to generate electricity through a CHP plant. The heat is used as fuel for the AD plant itself. An upgrading facility has been installed and a grid connection agreement has been signed with GNI which will facilitate a transition to the production of biomethane for direct injection into the gas grid.
- Feedstock: The business uses a combination of organic industrial and food waste as well as some slurry and agricultural waste products.

GreenGas AD

GreenGas is a farm-based, family-owned 1MW AD plant located in Shanagolden in Co Limerick.

- Output. The plant produces circa 2.4m M3 of biogas which is used to generate electricity through the on-site CHP facility. The electricity is sold to the grid under a Renewable Energy Feed in Tariff while the heat is used in the AD plant itself as well as on other on-farm activities. The resultant digestate (circa 20,000 tonnes annually) is used as an organic fertilizer in the associated on-farm dairy enterprise.
- Feedstock: The plant uses circa 21,000 tonnes of feedstock annually from a combination of poultry and dairy manure from the on-farm activities combined with other food and industrial organic wastes.

Biocore Environmental Limited

Biocore Environmental Ltd (BEL) operates a 1MW AD plant in Co Roscommon. Output: The company produces circa 3m M3 of biogas which is used to generate electricity in a CHP plant with the resultant heat utilised in the AD plant itself.

Feedstock: The plant uses a range of sludges, agricultural and industrial food waste in the AD plant.

Nephin Renewable Gas

Nephin Renewable Gas (NRG) was founded in 2024 as part of Nephin Energy which is owned by Canadian Pension Plan (CPP). NRG aims to become one of the largest biomethane producers in Ireland with plans for 20-30 AD facilities.

- Output. The plants are expected to vary in size depending on the availability of feedstock and access to demand. All are expected to produce biomethane for either direct injection into the gas grid or to be used as an alternative, renewable source of transport fuel.

- Feedstock: the company plans to use a combination of grass silage, other crop residues and animal slurry as the main feedstocks in its facilities. Each AD plant is expected to consume circa 30k tonnes of raw material annually. The resultant digestate is expected to be used by local farmers (feedstock suppliers) as an alternative to chemical-based fertilizers.

Appendix A1 - Germany

In 2023 Germany had 9,909 biogas plants producing 9.22bcm biogas, approximately half of EU biogas production. There plants are predominantly located in rural areas.

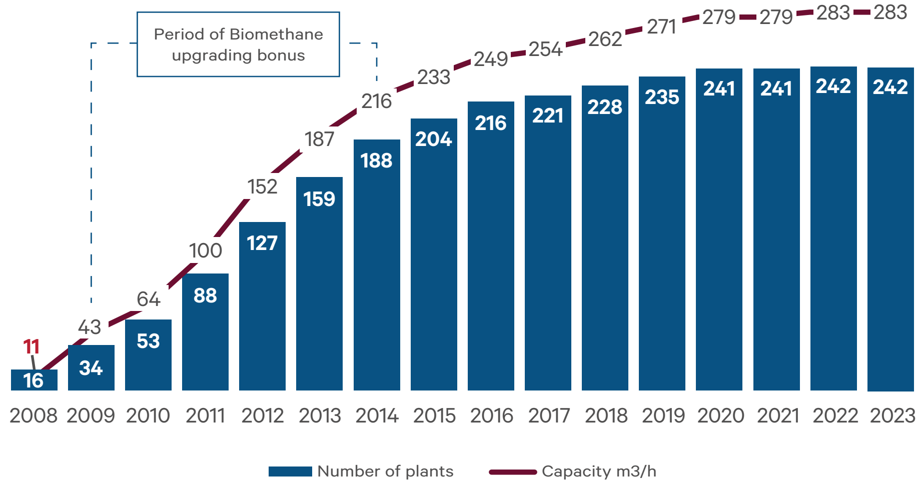
Germany first began producing biomethane by upgrading biogas in 2006. While just 2% of German biogas plants are upgrading to biomethane, Germany has quickly become the largest producer of biomethane, producing 1.3bcm of biomethane in 2021, 34% of biomethane made in Europe that year and c. 1.6% of natural gas demand in Germany. Germany now boasts over 240 biomethane plants. 2%

End use of biomethane is Germany is approximately 25% industry, 20% power generation, 17% building, 8% transport and 30% other/unknown.

Feedstocks across the c. 240 plants are estimated 78% energy crops, 14% Organic Waste, 7% agricultural residues and 1% sewage sludge.

The Renewable Energy Law (Erneuerbare-Energien-Gesetz-EEG) and its many revisions over the years helped grow the industry. The EEG was first introduced in 2000, targeting wide-spread adoption of renewable technologies, through fixed feed-in-tariffs, purchase guarantees and priority access to the grid. Three underlying pillars of the EEG are: (1) the right of grid connection for renewable energy facilities; (2) the obligation for network operators to preferentially purchase electricity based on renewables; and most notably (3) a minimum guaranteed feed-in-tariff to be paid for the generated electricity.

Figure A1-1. Biomethane production in Germany



Source: SiaPartners 2022 (2022 and 2023 data reversed out based on average capacity and current installations)

The evolution of the biogas market in Germany has followed a stage model: Introductory, Expansion, Consolidation and Stagnation.

Introductory Phase: Initial ground rules set by EEG in 2000 set up the subsidy in the form of a 50c/kWh subsidy for a 20-year period.

Expansion Phase: 2004 saw the act amendment offered higher tariffs to technologies which hadn't developed as well to date. Aswell as this, biogas CHP units with a production capacity below 5MW received an additional 2 c/kWh. As a result of the stacked incentives, the biogas sector grew rapidly.

Consolidation Phase: The booming biogas sector was seeing a large influx of private companies and cooperatives. 2009 saw support for small-scale biogas plants small biomass facilities with capacity below 150kW electricity seeing increased tariffs.
The 2009 amendments to the EEG also seeing a bonus for using manure/ slurry introduced, aiming to minimize reliance on maize feedstocks. Notably, 2009 saw the introduction of a biogas upgrading bonus, for those plants upgrading biogas to biomethane, remaining in place until 2014.

Revisions in 2012 saw a general decrease in biomass facilities tariffs by 10-15% on average, compared to 2009. 2012 saw further pressure on producers to limit use of energy crops, with a 2012 "maize cap", to limit the use of maize in biogas and to increase crop diversity. The biomethane upgrading bonus at this time was a 1-3c/kWh bonus.
Stagnation Phase: The upgrading bonus was then abolished in 2014, along with the substrate bonus for energy crops. From this point on the lack of biomethane specific support has slowed growth.

In 2017 the first renewable energy auction took place, under EEG 2017, replacing the previous feed-in tariff model, shifting to a market orientated price-finding model. EEG 2017 began 'expansion corridors' for bioenergy, at 150MW per annum until 2016, growing to 200MW then until 2022. A Price ceiling of 14.88c/kWh with a 1% degression per annum beginning 2018 was set. Projects under 150kW were not permitted for participation. Successful projects were to receive 20-year contracts.

The shift to an auction-based system has proved limited success. During the six-year period with an active biomethane upgrading bonus capacity grew at a CAGR of 31%, dropping to 3% in the six-year period following the abolishment of the bonus.

In 2023 the first oversubscribed auction for bioenergy plants with bids of 532MW exceeding the 300MW auctioned volume. However, of this only 29MW reflects new installations, reflective of 20-year subsidy programmes for existing plants ending.

Appendix A2 - Denmark

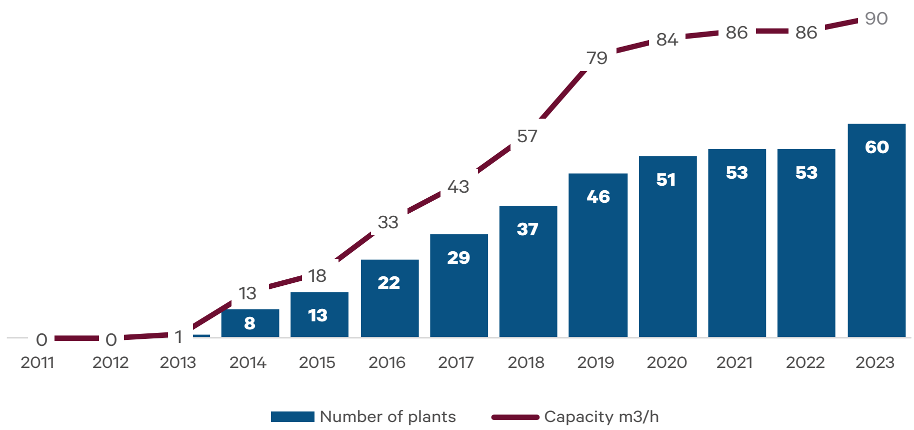
The Danish Government have ambitious target to replace 100% of natural gas consumption with biomethane by 2035.

Gas Networks Ireland has pointed to the success of the Danish biomethane journey. It took 25 years for Denmark to reach 38% of electricity production from wind and solar energy a very similar milestone has been achieved by the Danish gas industry in just 8 years i.e. 38% of gas consumption now comes from biomethane.

Biomethane is produced in 60 plants across the country. It is clear Denmark's biomethane market is rapidly growing and produced 15% of total European biomethane production in 2021 (0.6 bcm); by 2023 Denmark reached 40% gas consumption from biomethane.

Three quarters (75%) of feedstocks used in biomethane are agri-based, largely manure with some food waste/ municipal waste. Currently energy crops make up 10% of feed stocks. Denmark are phasing out their reliance on energy crops, with an ambition to reduce this to 5-7%

Figure A2. 1 Biomethane production in Denmark



Source: SiaPartners 2022. 2022/ 23 data reversed out based on average capacity and current installations

Biomethane was first injected into the gas grid in 2014. Henrik V Laursen, CEO of Bidadan has said that Denmark has succeeded by going from “farm-scale to largescale” plants.

Danish Biomethane is following a five step model: Local, Upgraded, Transmission, Interconnected and Continental

- Local: Production and consumption of biogas co-located
- Upgraded: Biomethane upgrading plants connected to distribution network. Currently 28% of biogas plants upgrade to biomethane, with 98% of those then injecting to the gas grid.
- Transmission: Reverse flow from DSO to TSO
- Interconnected: Cross-border flow of biomethane.
- Continental: Next step for Denmark

Minimum quotas for biofuels are imposed on the transport sector with fuel suppliers failing to fulfil the GHG reduction quotas facing potential fines.

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Reading List

- **Outlook for biogas and biomethane: Prospects for organic growth; World Energy Outlook special repor**t by the International Energy Agency.

Outlook for biogas and biomethane: Prospects for organic growth – Analysis - IEA

- **Food Waste Statistics** by the Environmental Protection Agency

Food Waste Statistics | Environmental Protection Agency (epa.ie)

- **Draft National Biomethane Strategy,** Prepared by the Department of Agriculture, Food and the Marine in partnership with Department of Environment, Climate and Communications.

gov - Consultation on the Draft National Biomethane Strategy (www.gov.ie)

- **Climate Action Plan -** This is the 4th edition of the Climate Action Plan often interchangeably referred to as CAP-24 or CAP-IV.

gov - Climate Action Plan 2024 (www.gov.ie)

- **Renewable Heat Obligation**

gov - Renewable Heat Obligation (www.gov.ie)

- **Davy White Paper: "Investing in Tomorrow: Shaping a Net-Zero Future" (1st November 2023) available at**

Investing in Tomorrow: Shaping a Net-Zero Future (davy.ie)

- **Renewable Energy Directive (various editions with RED-III latest)**

Renewable Energy Directive (europa.eu)

- **National Climate and Energy Plan –** this plan is published and maintained by each Member State Government and sent to the European Commission who in turn can then establish the status of the Union as a whole on its climate and energy commitments. This version of the Irish of the NECP (which updates an earlier edition from 2020) was prepared and published for consultation at a time (over the latter part of 2023) when negotiations on certain parts of the EU fit-for-55 package were ongoing (particularly RED-III and the Energy Efficiency Directive). Accordingly, the plan was labelled 'draft updated' and the subject of public consultation. We understand it is Government's intention to finalise this plan for submission in June 2024.

gov - Ireland's draft updated NECP 2021-2030 (www.gov.ie)

- **RePower EU**

REPowerEU (europa.eu)

- **Of particular interest is the accompanying Staff Working Document Implementing the RePower EU Action Plan: Investment Needs, Hydrogen Accelerator and Achieving the Bio-Methane Targets** eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230

- **ReFuel Aviation EU**

RefuelEU aviation initiative: Council adopts new law to decarbonise the aviation sector - Consilium (europa.eu)

- **Fuel Maritime EU**

FuelEU maritime initiative: Council adopts new law to decarbonise the maritime sector - Consilium (europa.eu)

- **"Statistical Report 2022 Tracking biogas and biomethane deployment across Europe" European Biogas Association**

EBA Statistical Report 2022 | European Biogas Association

- **A Review of Requirements and Constraints on Biofuels in Ireland Arising from RED II and National Targets prepared for DoT and NORA.**

gov - A Review of Requirements and Constraints on Biofuels in Ireland Arising from RED II and National Targets (www.gov.ie)

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- **National Heat Study**

National Heat Study | SEAI

- **Renewable Transport Fuel Policy 2023-2025**

262016_0f9661c4-30d8-4ecd-ae1d-eaa5b313d225 (2).pdf

- **Assessment of Cost and Benefits of Biogas and Biomethane in Ireland by SEAI**

Assessment of Costs and Benefits of Biogas and Biomethane (seai.ie)

- **Biomethane Energy Report by Gas Networks Ireland.**

biomethane-energy-report.pdf (gasnetworks.ie)

- **GNI issued and Request-for-Information on this subject and the product of this is contained in this report.**

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