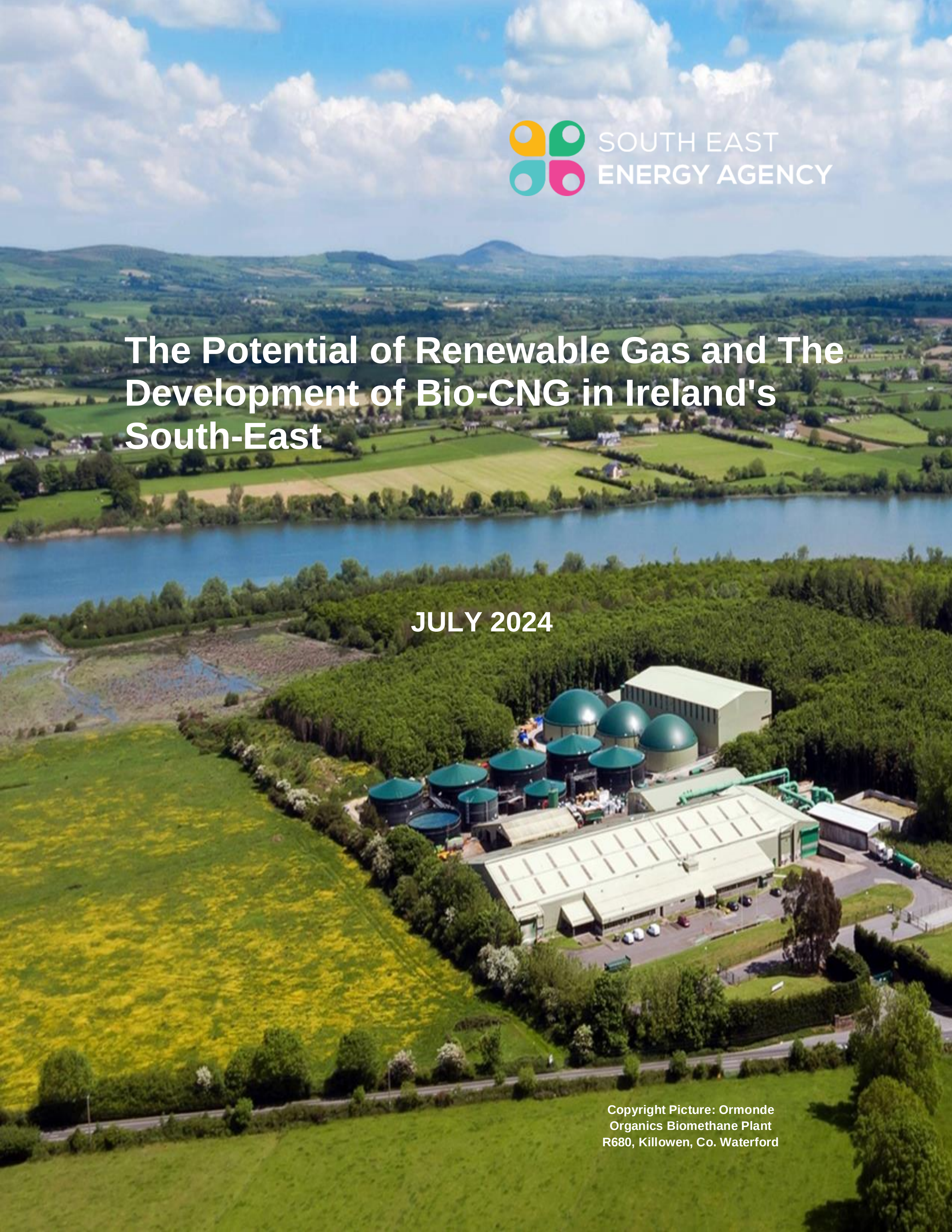
The Potential of Renewable Gas and The Development of Bio-CNG in Ireland's South-East

SOUTH EAST ENERGY AGENCY

JULY 2024



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Copyright Message

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List of Acronyms

AD	: Anaerobic Digestion
BEOFS	: Bio Energy Organic Fertiliser Services
Bcm	: billion cubic meters
CBM	: Compressed biomethane
CH4	: methane (Biomethane)
CHP	: Combined Heat Power
CNG	: Compressed natural gas
CO_2	: Carbon Dioxide
DM	: Dry matter
DWWTP	: Domestic Wastewater Treatment Plant
EU	: European Commision
EBA	: European Biogas Association
EPA	: Environmental Protection Agency
GIS	: Geographic Information Systems
GHG	: Greenhouse gas
GWh	: Gigawatt-hour or a million kWh
HGV	: Heavy Goods Vehicle
kWh	: Kilowatt-hour
LPG	: Liquid Petroleum Gas+
MWh	: Megawatt-hour
RE	: Renewable energy
RED	: Renewable Energy Directive
RES-e	: electricity produced from renewable energy sources
RES-heat	: Heat produced from renewable energy sources tCO2: tonne of CO2
SEAI	: Sustainable Energy Authority of Ireland
tDS	: Tonne Dry Sludge
tDM	: Tonne of Dry Matter
TWh	: Terawatt-hour, or a billion kWh
WWTP	: Wastewater Treatment Plant

Executive Summary

Background

The development of bioenergy in Ireland has been closely intertwined with its commitment to European Union policies such as the Renewable Energy Directive (RED) and RePowerEU. The country's National Bioenergy Plan, which ran from 2014 to 2020, focused on enhancing the contribution of bioenergy to Ireland's heat and transport sectors. This plan included initiatives for a stable biomass supply, demand-side measures for renewable energy, and support for research and development. However, in terms of meeting EU targets, Ireland's progress has been mixed. Under the 2009 Renewable Energy Directive, Ireland aimed to generate 16% of its energy from renewable sources by 2020, a target that was later updated to 32% by 2030. From 2005 to 2014, Ireland's renewable energy share grew from 3.1% to 8.6% of its total final consumption. Yet, by 2020, it reached only 13.5%, falling short of the 16% goal. In the broader EU context, bioenergy, primarily derived from agricultural, forestry, and organic waste, represented about 59% of renewable energy consumption in 2021. Ireland, aligning with EU-wide efforts, particularly focused on promoting biogas and biomethane, which are crucial for reducing reliance on imported fossil fuels. Despite these efforts, Ireland still faces challenges in fully realising its renewable energy potential and meeting its EU-mandated targets. Ireland lacks policies and legislation that support the development of an indigenous biomethane industry in comparison with other EU member states. Since fossil fuel prices have increased recently, a large gap has closed between the cost of production and market return. This gap must be bridged through policies, incentives, and financial support.

The Climate Action Plan 2021 puts in place 'a decarbonisation pathway' to 2030 to reach the EU Target of Net Zero emissions by 2050 in Ireland. This plan aims to address the observed and predicted climate changes affecting Ireland and the South-East Region. The South-East Region (Carlow, Kilkenny, Waterford, and Wexford) has an area of 7,198 km2, which represents over 10.2% of the total area of the state. The Region remains largely a rural Region with contrasting rural landscapes that range from the Atlantic seaboard to rich productive lands and river valleys. As of the 2022 census, the South-East region of Ireland had a population of 456,228, which constitutes 8.90% of the national population[1].

The development of indigenous bioenergy in Ireland not only reduces reliance on imported energy and enhances national energy security but also opens up a spectrum of new business prospects throughout the supply chain, including harvesting, transport, processing, and biogas production. Particularly beneficial for rural communities, this initiative offers a gateway to both direct and indirect employment opportunities, fostering wealth creation and economic growth in these areas. In Ireland, the transport sector, particularly heavy transport, is a major challenge in the context of emission reduction, accounting for 42% of the country's energy use. This sector is one of the most difficult to decarbonize due to its substantial energy demand.

[1] *Wikipedia.2023. South-East Region, Ireland. https://en.wikipedia.org/wiki/South-East_Region,_Ireland#:~:text=According%20to%20the%202022%20census%2C,regional%20capital%2C%20Waterford%2C%20was%2053%2C504. Accessed on 23th November 2023.*

Biogas development in the South-East region of Ireland: challenges and opportunities

The development of biogas in the South-East region of Ireland presents a blend of challenges and opportunities. A primary challenge is the initial investment required for biogas infrastructure, which includes costs for technology and skilled labor. Additionally, regulatory hurdles and securing consistent supply chains for organic feedstock can be significant obstacles. The region, however, also offers fertile ground for biogas development. Its strong agricultural sector provides an ample supply of raw materials, such as animal manure and crop residues, which are essential for biogas production. There's also a growing awareness and support for renewable energy sources in the area, further buoyed by government incentives and policies aimed at reducing carbon emissions. The integration of biogas facilities can also create local employment opportunities and contribute to rural development. Furthermore, biogas production aligns well with the region's environmental goals, offering a sustainable way to manage waste and reduce greenhouse gas emissions. Thus, while there are hurdles to overcome, the prospects for biogas development in South-East Ireland are promising, with potential economic, environmental, and social benefits.

Biogas, a biofuel produced from the decomposition of organic waste through anaerobic digestion, can be generated from materials such as animal slurry, energy crops, food waste, grass silage, and farm-animal waste. As a predominantly rural region, the South-East region has significant bioenergy potential based on agricultural lands, forestry, and waste residues from municipal, agricultural, and industrial sources. Biogas can supply 8% of the overall energy demand in the South-East region, which accounts for 8.9% of its total energy demand (Figure 1)[2]. A total of 1,080 GWh of biogas can be produced from the various feedstocks currently available in South-East region (Carlow, Kilkenny, Wexford, and Waterford).

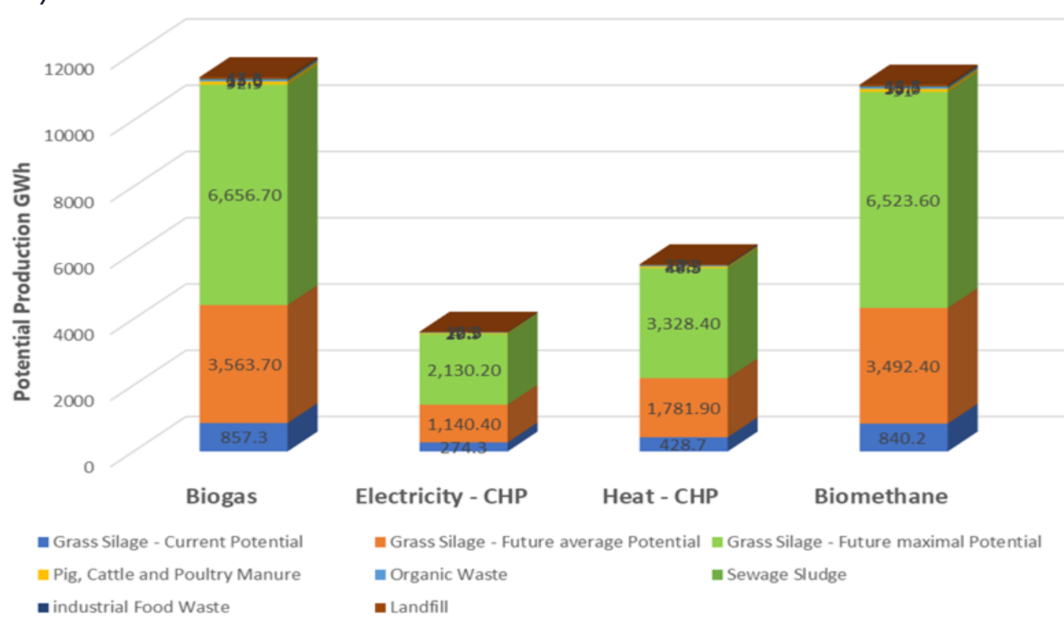

Figure 1. *Biogas production from key resources (grass silage, animal manure, organic waste, sewage sludge, industrial food waste, landfills).[2]*

[2] XDConsulting.2022. South-East Region Bioenergy Implementation Plan. RegEnergy final report. South East Energy Agency.

Biomethane, the core component of Bio-CNG, is structurally identical to natural gas and is fully compatible with the national gas network, existing appliances, technologies, and vehicles. This compatibility facilitates a smooth transition from natural gas to a more sustainable fuel alternative. Gas Networks Ireland has been actively involved in increasing the availability of domestically produced biomethane and developing a coordinated gas network plan to efficiently distribute biomethane across Ireland. This report presents a comprehensive analysis of the availability of feedstock for Anaerobic Digestion (AD) plants, assessing the net availability of methane in raw biogas and its potential use for renewable energy production, specifically in the form of biogas and hydrogen.

In the South-East region, the current potential for raw biogas production from various sources is estimated at approximately 987 Gigawatt-hours (GWh). With optimal resource management, this potential could significantly increase to about 6,671 GWh[2]. Grass silage emerges as the most substantial contributor to both current and future biogas and hydrogen production. The current potential of biogas from grass silage is approximately 840 GWh, or 619 GWh if converted into hydrogen. With improved resource management, this figure could rise to 6,524 GWh of biogas, equivalent to approximately 4,804 GWh of hydrogen annually. Animal slurry, particularly from pigs, cattle, and poultry, is another notable source of biogas, despite its dispersed nature across rural areas. The total biogas potential of animal slurries (pigs, cattle, and poultry) is estimated at about 67 GWh annually, which, if converted to hydrogen, would result in about 49 GWh. Wastewater Treatment Plants (WWTPs) in the South-East region analysed also hold substantial potential for methane production, which can be used for hydrogen generation. The total biogas potential from WWTPs is estimated at 9.9 GWh, or approximately 7.3 GWh of hydrogen per year. Additionally, landfills are identified as a significant source of biogas, with a net potential of about 48 GWh, or 35 GWh of hydrogen annually.

Table 1. *Potential biogas and Hydrogen production and share of regional energy demand* [2]

	Biogas		Hydrogen	
	Potential Production [GWh]	Share of overall energy demand in South-East region	Potential Production [GWh]	Share of overall energy demand in South-East region
Grass Silage - Current Potential	840.16	7%	618.78	5.1%
Grass Silage - Future average Potential	3492.45	28%	2572.18	21.2%
Grass Silage – Maximal Potential	6523.64	53%	4804.64	39.6%
Pig, cattle, and poultry Manure	68.38	1%	49.36	0.4%
Organic Waste	54.64	0.3%	39.44	0.3%
Sewage Sludge	10.09	0.1%	7.29	0.1%
Industrial Food Waste	16.91	0.1%	12.46	0.1%
Landfill	47.76	0.3%	35.18	0.3%
Total - Current Potential	987.54	8%	727.32	6.0%
Total - Future average Potential	3639.83	30%	2680.73	22.1%
Total – Future maximal Potential	6671.02	54%	4913.19	40.5%

Biomethane production and the potential for CNG filling station expansion in the regional market

The Irish market for biomethane production in the South-East region is an emerging and vital sector, driven by Ireland's commitment to renewable energy and sustainable practices. This region, characterised by its robust agricultural activities, offers a significant supply of organic feedstock necessary for biomethane production. This includes a variety of resources like animal manure from dairy and beef farms, crop residues, and potentially energy crops. The presence of anaerobic digestion (AD) facilities in the region plays a crucial role in the conversion of these organic materials into biomethane. These facilities not only help in managing agricultural waste but also contribute to the production of renewable energy.

The infrastructure for biomethane in this area includes a network of processing plants, pipelines for distribution, and systems for upgrading biogas to biomethane, which is essential for its utilization as a fuel. The growth of the biomethane market in South-East Ireland is influenced by both government and private investments, reflecting a growing interest in renewable energy sources. Environmental benefits such as the reduction of greenhouse gas emissions and improved waste management practices also add to the appeal of biomethane production.

However, the market's development faces challenges like logistical issues in feedstock collection and distribution, high production costs, and regulatory hurdles. Despite these challenges, the demand for biomethane is steadily increasing, particularly for uses in heating, electricity generation, and as a sustainable alternative for transport fuel. This growing demand is supported by a favorable policy and regulatory framework that encourages renewable energy initiatives, including biomethane production. Overall, the biomethane market in Ireland's South-East region presents a promising opportunity for sustainable energy production, aligning with both environmental goals and economic development. In the South-East region of Ireland, despite having six operational anaerobic digestion (AD) plants (BEOFS (Bio Energy Organic Fertiliser Services), Ballyshannon Recycling Ltd. Malcolm Rothwell, Ormonde Organics, Kilgreany AD, and Ashleigh farms, Biowave) , there exists a significant potential to expand biogas and biomethane production capacity, particularly in light of the narrowing cost gap between production and market returns due to recent increases in fossil fuel prices. Bridging the gap between farmer engagement and income diversification through targeted policies, incentives, and support has become increasingly vital, serving as a key incentive for AD investors in recent years.

The introduction of Bio-CNG in the South-East stands out as a strategic move to reduce carbon emissions in the transport sector, particularly for heavy goods vehicles. Given that transportation is a major contributor to Ireland's greenhouse gas emissions, the switch to Bio-CNG represents a critical step towards decarbonisation. This initiative is supported by the development of infrastructure, such as refueling stations at key locations, enabling a smoother transition for commercial transport fleets. Moreover, the adoption of Bio-CNG resonates well with Ireland's commitment to the EU's climate goals. Using biomethane-based Bio-CNG is reducing Ireland's carbon footprint and enhancing its energy security by reducing the need for imported fuel. The role of biomethane in this process is significant, given its compatibility with the existing gas network and its potential to seamlessly replace natural gas. The study also presents potential locations to have a Natural Gas/Biomethane refueling facility in the South-East region for HGV’s and Bus fleets. There are 19 locations that with suitable support could provide facility for a grid CNG connection. This report uses Geographic Information Systems (GIS) to identify the potential CNG fueling stations for HGV’s and buses which meet the criteria outlined by GNI.

This study aims to comprehensively assess the South-East region's capacity for sustainable feedstock production, the environmental and economic impacts of Bio-CNG development, and to outline strategic recommendations for implementing this initiative effectively.

1.0 Introduction

In the pursuit of sustainable energy solutions, the exploration of renewable gas, particularly bio-CNG (Compressed Natural Gas), has emerged as a vital area of focus. This report delves into the evaluation of renewable gas potential and the development prospects of bio-CNG in Ireland's South-East region. Ireland, with its increasing emphasis on renewable energy sources, presents a unique landscape for investigating these alternatives.

The South-East Region of Ireland, with its rich agricultural base, urban waste management capabilities, existing biogas infrastructure, and supportive policy environment, could hypothetically hold around 35-55% of the country's total potential for renewable biogas production. A major contributor to biogas potential is the region's robust dairy and livestock farming, especially in counties like Wexford and Kilkenny. The anaerobic digestion of animal manure from these farming activities is a key process in biogas production. Considering the scale of agricultural activities here, it could be hypothesized that this sector alone might contribute around 20-30% to the region's biogas potential.

Furthermore, existing biogas facilities in Carlow, which process agricultural and municipal waste, directly impact the county's biogas output. The capacity and efficiency of these facilities are key: if they operate at high efficiency, Carlow's contribution to Ireland's biogas production could see a significant boost.

Urban centers, such as Waterford City, also play a pivotal role in shaping the biogas landscape. Efficient waste management systems in these areas, capable of processing municipal and industrial waste into biogas, could add another layer to the region's potential. Optimising these systems might feasibly contribute an additional 10-15% to the renewable biogas resources in the South-East Region.

Existing biogas facilities in the region further augments this potential. If these facilities, operating at varied efficiencies, were to optimise their processes, they could significantly enhance the overall biogas output. An estimated efficiency improvement from 50-70% in these facilities could substantially raise the region's contribution to Ireland's biogas production. Environmental policies and governmental support are also crucial factors. The development of bio-CNG in Ireland's South-East is not only a step towards energy independence but also a stride towards a cleaner, more sustainable future. This report, through its detailed analysis and evaluation, aims to provide a roadmap for harnessing this potential, paving the way for a greener and more prosperous Ireland.

POLICY CONTEXT

2.0 Policy Review

Ireland aims to reduce greenhouse gas emissions from its energy sector by 80% to 90% compared to 1990 levels by 2050. This target necessitates a radical transformation of the country's energy system, with a shift towards generating electricity from renewable sources, transitioning from high-emission fuels to lower-emission alternatives like gas, and ultimately moving away from fossil fuels. The focus on biogas and biomethane in this context is significant, as these renewable energy sources offer potential for electricity and heat generation, as well as for replacing natural gas. The development of the biomethane sector in Ireland is contingent upon comprehensive policy frameworks and actionable strategies. The economic assessment of the increase in biogas and biomethane supply, as mandated in the draft Bioenergy Plan and the energy white paper, includes evaluating the economic costs and benefits, alongside wider advantages such as improved waste management and broader economic impacts. This approach aligns with EU directives and strategies, including the Renewable Energy Directive and the Green Deal, which emphasize renewable energy and carbon reduction goals. Ireland's commitment to exploring and expanding the role of biogas and biomethane in its energy mix is a crucial part of its strategy to meet these stringent and transformative energy and climate targets.

2.1 EU Legislation and Policy

2.1.1 REPowerEU

Ireland's approach to biogas and biomethane is increasingly framed within the broader context of the European Union's ambitions, particularly those articulated in the RePowerEU Plan. RePowerEU, launched in response to the global energy crisis exacerbated by geopolitical tensions, aims to rapidly reduce dependence on fossil fuels and enhance energy security through an accelerated clean energy transition. Biomethane, as a renewable energy source, plays a crucial role in this plan due to its potential to replace natural gas in existing infrastructure. The REPowerEU Plan is a pivotal element in understanding the context for Ireland's commitment to expanding the role of biogas and biomethane in its energy mix. Key achievements of the REPowerEU Plan include reducing dependency on Russian fossil fuels, saving almost 20% of energy consumption, implementing gas and oil price caps, and notably doubling the deployment of renewables[3].

The REPowerEU plan, with its proposal to accelerate the production of sustainably produced biomethane, aligns closely with Ireland's commitment to expand its biogas and biomethane sector. This EU initiative aims to reduce reliance on imported fossil fuels and address the climate crisis by increasing biomethane production to 35 billion cubic meters (bcm) per year by 2030, necessitating an estimated investment of €37 billion. Ireland, with its sustainable biomethane potential estimated at 0.7 bcm from Anaerobic Digestion (AD) by 2030, represents a Member State with moderate potential in contributing to this target, but with significant national benefits from a developed biomethane market (see figure 2). Ireland's consumption of significant amounts of nitrogen and phosphorus fertilizers, which could be partially replaced by digestate from biomethane production, underscores this potential. Furthermore,

[3] *European Commision.2022. RePowerEU plan. https://eur-lex.europa.eu/resource.html?uri=cellar:fc930f14-d7ae-11ec-a95f-01aa75ed71a1.0001.02/DOC_1&format=PDF. Accessed on 23 November 2023.*

with agriculture, forestry, and fisheries being the main sources of greenhouse gas emissions in Ireland, accounting for 41% (22 $MtCO_{2eq}$), the development of the biomethane sector through manure management in AD and low emission application techniques of digestate on soil presents a valuable opportunity for significant emissions mitigation in line with EU goals[4]. Through investing in renewable gas technologies and infrastructure, Ireland is not only advancing its own energy and climate targets but is also actively participating in the broader EU ambition of a greener, more secure energy landscape.

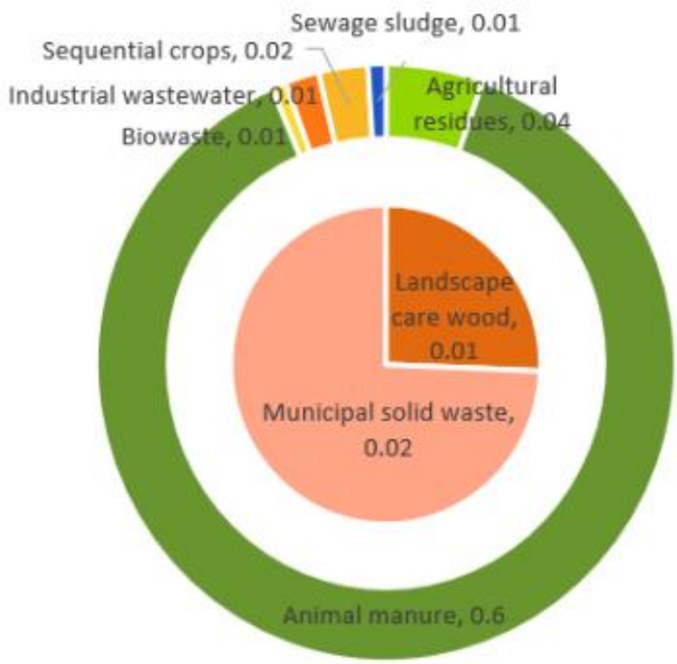

Figure 2*.Biogas/biomethane potential (in bcm), by feedstock for Ireland (inner pie gasification and outer circle AD)[4]*

Ireland's national strategies for biogas and biomethane, in conjunction with RePowerEU, focus on several key areas:

1. **Enhanced Investment and Support:** Providing financial incentives and support schemes to stimulate investment in biogas and biomethane production, aligning with RePowerEU's emphasis on bolstering renewable energy investments.
2. **Innovation and Technology:** Promoting research and development to advance technologies in biogas production and biomethane upgrading, resonating with RePowerEU's call for technological innovation to facilitate the clean energy shift.
3. **Infrastructure and Integration:** Building and upgrading infrastructure to accommodate biomethane, including gas networks and CNG/LNG stations, supporting RePowerEU's vision of integrating renewable gases into the European energy system.
4. **Regulation and Standards:** Developing a supportive regulatory framework to foster the growth of the biogas and biomethane sector, in line with RePowerEU's objective of creating a favorable environment for renewable energies.
5. **Sustainability and Environmental Standards:** Ensuring that biogas and biomethane production meet high sustainability criteria, in accordance with RePowerEU's sustainability goals.

[4] *European commission. 2021. Biomethane Fiche – Ireland. https://energy.ec.europa.eu/system/files/2023-09/Biomethane_fiche_IE_web.pdf. Accessed on 23 November 2023.*

2.1.2 EU Green Deal

Ireland's policy on biogas and biomethane is closely aligned with the European Union's Green Deal, which is a comprehensive package of policy initiatives aimed at achieving climate neutrality across the EU by 2050[5]. Biomethane, a renewable energy source produced by the anaerobic digestion of organic matter, is a key component in the EU's strategy to reduce greenhouse gas emissions, enhance energy security, and transition to a circular economy. The Irish government has set a target of replacing roughly 3% of Ireland's current gas-powered energy with biomethane powered alternatives by 2030[6].

The European Green Deal provides a framework and set of objectives that can guide and support Ireland in expanding its biomethane production. Ireland, with its strong agricultural sector, is uniquely positioned to contribute to and benefit from this aspect of the Green Deal. Here's how the European Green Deal relates to Ireland's biomethane production:

EU Farm to Fork Strategy[7]: This strategy is a core part of the Green Deal, aiming to facilitate the transition to a sustainable food system with a neutral or positive environmental impact. It underscores the role of biomethane in reducing the environmental and climate footprint of primary food production, highlighting its contribution to a circular bio-based economy. The EU Farm to Fork Strategy, promotes sustainable food systems. Ireland can leverage this strategy to enhance the sustainability of its agricultural practices. The country's extensive livestock farming, and crop production provide ample raw materials for biomethane production, including livestock manure and crop residues.

Figure 3. *EU Farm to Fork Strategy[6]*

EU Methane Strategy[8]: This strategy emphasizes the role of biogas from agricultural waste in mitigating methane emissions, a significant greenhouse gas. It envisages creating new revenue streams for farmers and contributing to rural development, with a particular focus on sustainable biogas production practices such as sequential cropping with manure as feedstock. Ireland's investment in biomethane production from agricultural waste not only aligns with this strategy but also helps in mitigating the country's methane emissions. By processing agricultural waste into biomethane, Ireland can turn a potent greenhouse gas source into a clean energy resource.

EU Circular Economy Action Plan[9]: this action plan seeks to shift Europe from linear to circular economic models, emphasizing resource longevity and recycling. It supports the sustainable and circular bio-based sector, notably through the Bioeconomy Action Plan, and considers the development of regulatory frameworks for certifying carbon removals. In Ireland, the production of biomethane can

[5] EU representative in Ireland. 2023. The Environment: Ireland's Green Deal. https://ireland.representation.ec.europa.eu/strategy-and-priorities/key-eu-policies-ireland/environment-irelands-green-deal_en. Accessed on December 20, 2023.

[6] Energy Ireland. 2022. Biogas development crucial for energy independence. https://www.energyireland.ie/biogas-development-crucial-for-energy-independence/. Accessed on 18 October 2023.

[7] European Commission. 2020, Farm to Fork strategy. https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en. Accessed on 18 October 2023.

[8] European Commission. 2020, Methane emissions. https://energy.ec.europa.eu/topics/oil-gas-and-coal/methane-emissions_en#eu-methane-strategy Accessed on 18 October 2023

[9] European Commission. 2015, Circular economy action plan. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en. Accessed on 18 October 2023

support a circular economy by recycling agricultural waste and by-products into energy, thereby reducing waste, and enhancing energy self-sufficiency.

EU Forest Strategy*[10]*: This strategy highlights the multifaceted role of forests in rural development, biodiversity, and climate change mitigation. It aligns with the Green Deal by promoting the sustainable use of forest resources for bioenergy within ecological boundaries.

***EU Biodiversity Strategy*[11]**: Aimed at reversing ecosystem degradation, this long-term strategy sets forth commitments to restore and enhance biodiversity by 2030. It includes targets relevant to agriculture, such as increasing high-diversity landscape features and organic farming.

Common Agricultural Policy (CAP)*[12]*: The CAP supports the agricultural sector through direct payments, rural development investments, and environmental protection measures. The new CAP, aligned with the Green Deal, aims to foster the sustainable development of farming and the food sector, enhancing farm incomes and competitiveness while incorporating the EU's climate ambitions.

Figure 4 below visualizes the hypothetical impact of various EU policies on the development of the bioenergy sector, specifically biogas and biomethane production. Each policy—ranging from the "Farm to Fork" strategy to the reformed Common Agricultural Policy (CAP)—is scored based on its perceived contribution to fostering bioenergy development. These impact scores reflect the synergistic effects of EU policies under the Green Deal framework, highlighting the collective drive towards a sustainable, circular, and bio-based economy. The graph serves as a visual representation of how integrated policy efforts at the EU level can significantly influence the growth and sustainability of bioenergy sectors across member states, including Ireland.

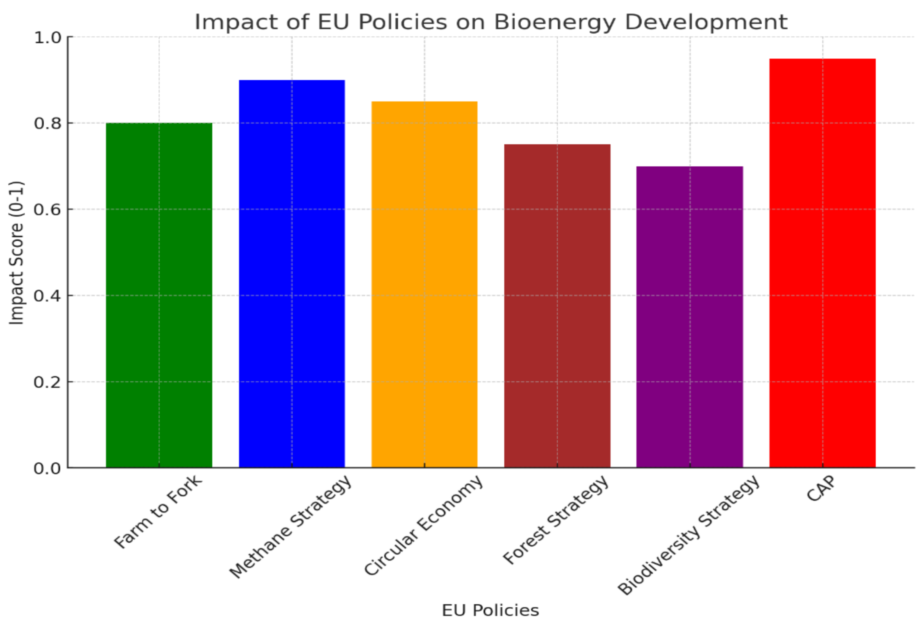

Figure 4. *The synergy between EU policies and the growth of the biogas and biomethane sector.*

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[10] *European Commission. 2019, New EU Forest strategy for 2030. https://environment.ec.europa.eu/strategy/forest-strategy_en. Accessed on 18 October 2023*

[11] *European Commission. 2020, Biodiversity strategy for 2030. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en,Accessed on 18 October 2023*

[12] *European Commission. 2021, Common agricultural policy. https://www.consilium.europa.eu/en/policies/cap-introduction/#:~:text=The%20CAP%20is%20a%20set,quality%20food%20for%20EU%20citizens. Accessed on 18 October 2023.*

2.2 Irish Policies for Bioenergy Development

2.2.1 Climate Action and Low Carbon Development Act 2023

Ireland's Transition to a Low Carbon Energy Future 2015-2030 sets out a vision for transforming Ireland's fossil fuel-based energy sector into a clean, low carbon system by 2050. Policy interventions that promote renewable energy generation through supports such as the public service obligation levy is an example of a measure taken towards achieving this transition and achieving our climate change commitments. Supporting actions will focus on renewable energy, energy efficiency, sustainable transport, agriculture, forestry, and climate resilience.

In comparison with other EU member states, Ireland lacks policies and legislation that support the development of an indigenous biomethane industry. The implementation of many acts, regulations, guidelines, and standards indirectly addresses sustainability by addressing related subject areas, such as land use and good agricultural practices. However, the sustainability of solid or gaseous biomass in Ireland is not governed by any legislation.

The "Climate Action and Low Carbon Development Act 2023" marks a significant step forward in Ireland's commitment to climate action and the transition to a low-carbon economy. This legislation sets ambitious targets for reducing greenhouse gas emissions and achieving net-zero emissions by 2050, in line with global climate agreements and European Union directives. The "Climate Action and Low Carbon Development Act 2023" marks a significant step forward in Ireland's commitment to climate action and the transition to a low-carbon economy. This legislation sets ambitious targets for reducing greenhouse gas emissions and achieving net-zero emissions by 2050, in line with global climate agreements and European Union directives[13].

The Irish "Climate Action and Low Carbon Development Act 2023" establishes a robust framework for the country's transition to a sustainable, low-carbon economy by setting ambitious climate action targets. This Act is a response to the urgent need for climate mitigation and adaptation, aiming to align national policies with international commitments to combat climate change. The targets set under this Act reflect Ireland's dedication to reducing its greenhouse gas emissions and enhancing climate resilience across various sectors. Here are the key targets in various sectors:

1. **Powering Renewables**: Ireland aims to increase the share of renewables in its energy mix, targeting 80% renewable electricity by 2030, a significant step up from previous goals.
2. **Buildings**: The target includes retrofitting 500,000 homes to achieve a B2 Building Energy Rating (BER) by 2030 and implementing stringent energy efficiency standards for new constructions.
3. **Transport**: Ireland plans to drastically reduce emissions in the transport sector, with a goal of having 1 million electric vehicles on the road by 2030.
4. **Climate Mitigation and Adaptation**: Comprehensive strategies are in place to enhance the resilience of communities, ecosystems, and the economy to climate-related impacts, alongside efforts to reduce overall carbon emissions.

[13] *Government of Ireland. 2023, Climate Action Plan 2023.* https://www.gov.ie/en/publication/7bd8c-climate-action-plan-2023/. *Accessed on 18 October 2023.*

5. **Business and Industry**: The Act encourages the decarbonization of industrial processes and the adoption of green technologies, aiming for a substantial reduction in the carbon footprint of business and industrial activities.
6. **Land Use**: Initiatives to improve land use practices include afforestation, peatland restoration, and sustainable agriculture, aiming to enhance carbon sequestration and biodiversity.
7. **Government**: The public sector is expected to lead by example, with targets set for carbon neutrality in all government operations by 2030.

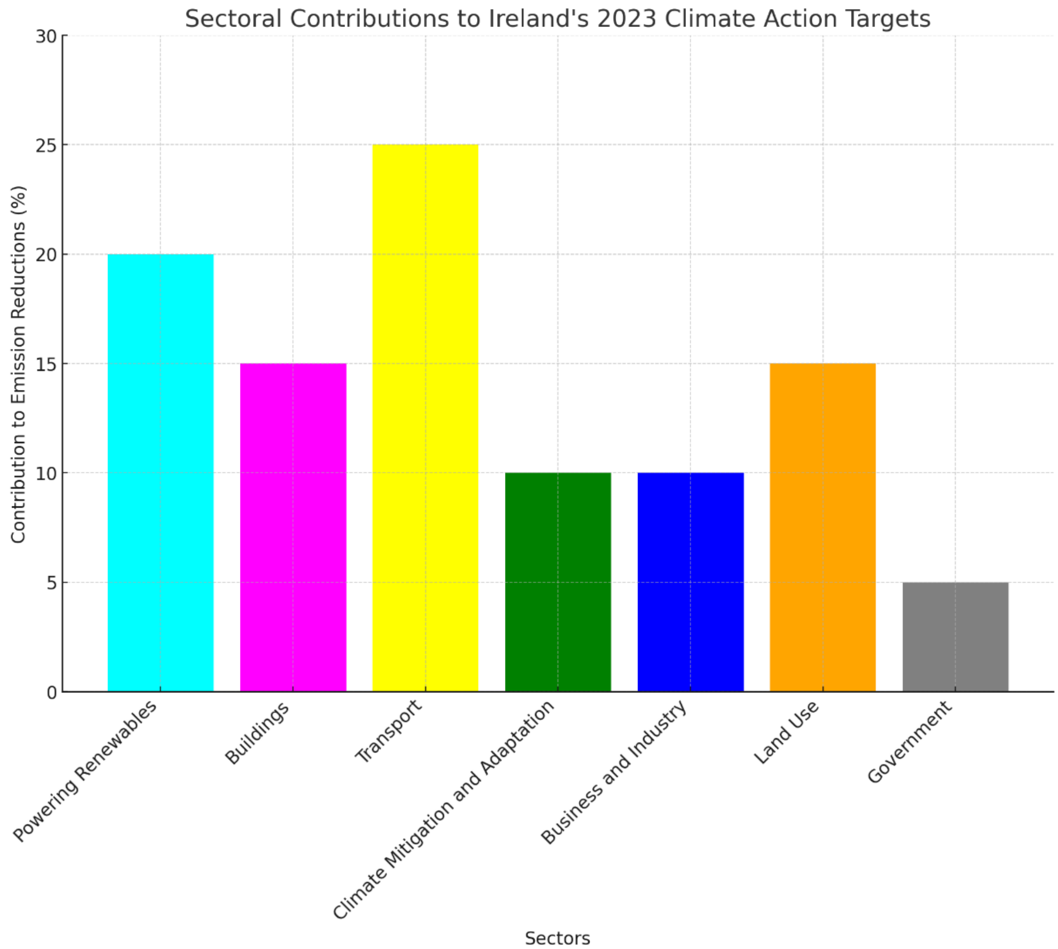


Figure 5. *Key target sectoral in Climate Action and Low Carbon Development Act 2023*

Figure 5 illustrates the hypothetical contributions of different sectors to meeting Ireland's climate action targets as set out in the "Climate Action and Low Carbon Development Act 2023." The transport sector is projected to have the largest contribution, reflecting the ambitious goal of having 1 million electric vehicles on Irish roads by 2030. The powering renewables sector also plays a significant role, aligning with the target of 80% renewable electricity by 2030. Other sectors, such as buildings, land use, and business and industry, contribute notably through initiatives like home retrofits, sustainable land management practices, and the decarbonisation of industrial activities. The government sector, though contributing the least in percentage terms, is crucial for setting standards and leading by example towards carbon neutrality. This figure 5 underscores the importance of a comprehensive, cross-sectoral approach to achieving Ireland's ambitious climate action and low-carbon development goals for 2023.

2.2.2 The National Renewable Energy Action Plan (NREAP) of Ireland

The National Renewable Energy Action Plan (NREAP) of Ireland is a comprehensive plan mandated by the European Union, detailing how Ireland intends to achieve its legally binding target of a 16% share of energy from renewable sources by 2020. This target is part of the broader EU goal to increase the share of renewables in energy consumption across the bloc. The NREAP of Ireland places significant emphasis on the development of renewable energy sources, including biomethane. Biomethane production plays a significant role in Ireland's NREAP for several reasons:

Diversification of Energy Sources: The NREAP emphasizes the diversification of Ireland's energy sources, moving away from heavy reliance on imported fossil fuels. Biomethane, as a locally produced renewable energy source, is instrumental in this diversification. It provides a sustainable alternative to natural gas and other non-renewable energy sources.

Renewable Energy in the Transport Sector: The NREAP includes targets for renewable energy in the transport sector, where biomethane can be utilized as a biofuel. Biomethane is particularly suitable for heavy goods vehicles, buses, and other forms of transport, helping to reduce carbon emissions in this sector.

Sustainable Agriculture and Waste Management: The plan recognizes the role of sustainable agricultural practices and efficient waste management in renewable energy production. In Ireland, where agriculture is a key sector, the production of biomethane from agricultural waste (like livestock manure) and food waste aligns with these objectives, turning waste streams into energy resources.

Supporting Rural Economies: The NREAP acknowledges the role of renewable energy in supporting rural economies. Biomethane production facilities can provide new revenue streams for farmers and rural communities, contributing to rural development and sustainability.

Meeting EU Renewable Energy Directives: Ireland's NREAP is designed to comply with EU directives on renewable energy. Through investing in biomethane production, Ireland works towards meeting its EU-mandated renewable energy targets.

Financial Incentives and Support Mechanisms: The plan outlines financial incentives and support mechanisms for renewable energy projects, including biomethane. This includes grants, subsidies, and other forms of financial assistance to stimulate investment in biomethane production.

Research and Development: The NREAP also focuses on research and development in the renewable energy sector. This includes developing new technologies and processes for more efficient and cost-effective biomethane production.

2.2.3 National Hydrogen Strategy

Ireland's National Hydrogen Strategy marks a significant step in the country's journey towards a sustainable energy future. This strategy, a cornerstone of the Hydrogen and Climate Action Plan 2023, lays out a comprehensive framework for hydrogen production and usage within Ireland's energy system. Central to this strategy is the goal of developing the hydrogen sector, with a specific emphasis on leveraging Ireland's robust offshore wind resources. By 2030, the plan is to have 7 gigawatts (GW) of offshore wind capacity operational, including a dedicated 2GW to produce green hydrogen[14]. Currently, hydrogen, predominantly used in industrial processes like oil refining and the production of ammonia and methanol, constitutes less than 2% of the EU's energy consumption, and most of it is carbon-intensive "grey" hydrogen, produced from hydrocarbons without mitigating the carbon emissions generated during its production, rendering it a non-sustainable energy form. Figure 6 below shows Green hydrogen's value chain consists of multiple elements that are intertwined with other sectors of the energy industry[15].

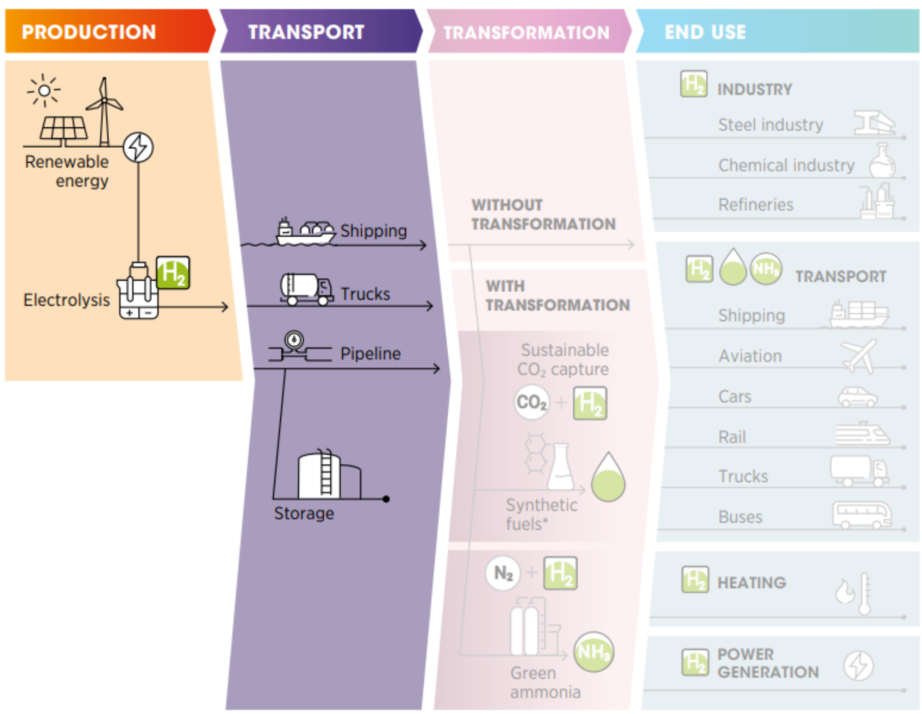


***Figure 6**. Green hydrogen value chain[15]*

Ireland's ambitious goal of achieving 80% renewable electricity by 2030 is primarily aimed at decarbonising power generation and facilitating the growing electrification of heat and transport sectors. However, the Climate Action Plan 2023 reveals that this target could also enable the production of 2-4 TWh of renewable hydrogen by 2030. This potential is expected to increase significantly with the forthcoming detailed design of the electricity network, as outlined in the second version of shaping Ireland's electricity future. Notably, hydrogen is anticipated to play a crucial role in reducing system

[14] *Government of Ireland. 2023. National Hydrogen Strategy. https://www.gov.ie/en/publication/624ab-national-hydrogen-strategy/. Accessed on 30 November 2023*

[15] *IRENA. 2021. Green Hydrogen Supply: A Guide to Policy Making. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/May/IRENA_Green_Hydrogen_Supply_2021.pdf. Accessed on 30 November 2023.*

curtailment, which is projected to be around 16% (or 9.7 TWh) by 2030. Looking towards the future, Ireland's Framework sets a vision for 20 GW of offshore wind energy production by 2040 and at least 37 GW by 2050. This expansion provides a substantial opportunity to increase renewable hydrogen production post-2030. Central to this vision is the scale-up and production of renewable hydrogen, which, in the period leading up to 2030, will be predominantly produced through grid-connected electrolysis using surplus renewable energy. This method aligns with EU targets and is expected to bolster the power system. The strategy involves developing operating models beneficial to the electricity system and ensuring robust grid infrastructure. The target of establishing 2GW of offshore wind capacity specifically for renewable hydrogen production by 2030 is poised to offer greater investment certainty and create the necessary volumes for sectoral expansion. Leveraging Ireland's exceptional offshore wind resources, the strategy positions the country not only to meet its domestic energy needs but also to become a long-term net exporter of renewable hydrogen, capitalising on its natural resources and strategic investments.

The dynamics influencing low-carbon hydrogen consumption in various sectors (such as electricity, buildings, industry, transportation, and agriculture) and its impact on decarbonization are multifaceted, shaped by the interplay of demand and supply as illustrated in Figure 7. Policymakers face challenges on both fronts, demanding a nuanced approach. The policy should aim to boost stakeholder trust by backing demonstrations of hydrogen technologies to affirm their deployment readiness. It should also prioritise certain low-carbon (green) hydrogen production pathways, foster the development of hydrogen infrastructure through direct or indirect incentives, stimulate demand in scenarios where green hydrogen's selling price is high, and establish a certification mechanism for green hydrogen[16].

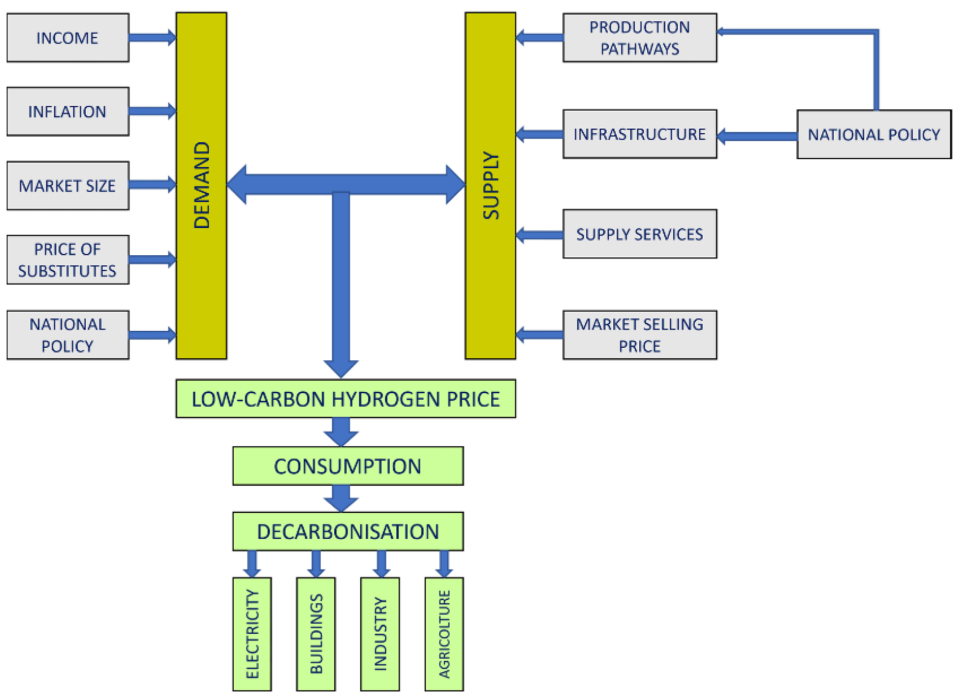


Figure 7. *Relationships between the factors that determine uptake of green hydrogen and role of a national policy*[16].

[16] *Tommasi,LD and Lyons,P.2023. Towards the Integration of Flexible Green Hydrogen Demand and Production in Ireland: Opportunities, Barriers, and Recommendations. Energies 2023, 16(1), 352; https://doi.org/10.3390/en16010352. Accessed on 30 November 2023.*

3.0 Ireland's Roadmap to Renewable Gas

Ireland's Roadmap to Renewable Gas, central to its net zero strategy, focuses on decarbonising its gas network through the introduction of renewable gases, especially biomethane. This shift is particularly significant given Ireland's substantial agri-food sector, where renewable gas production from agricultural activities is seen as a viable option for sustainable farming and rural job creation. Biomethane, a flexible and storable fuel, is already being integrated into Ireland's national gas network and requires no adjustments to existing natural gas distribution equipment.

Key policy measures underpinning this transition include the Climate Action Plan 2023 (CAP23), which targets up to 5.7 TWh of biomethane production by 2030 using agricultural feedstocks, tripling previous ambitions. The development of a National Biomethane Strategy aims to outline actions for achieving these targets. The strategy leverages Ireland's strong agricultural sector to produce biomethane, contributing to the country's broader goals of energy sustainability and decarbonisation.

The strategy is backed by several policy measures that support this development. These include the introduction of the Renewable Heat Obligation Scheme (RHO Scheme), planned for 2024, which incentivizes investment in the renewable gas sector. Additionally, the introduction of Guarantees of Origin (GOO) for gas from renewable sources in 2022 allows for tracking and verification of renewable gas origin. The Biofuels Obligation Scheme (BOS), although established earlier in 2010, remains relevant for encouraging the use of sustainable biofuels in transportation, further supporting the transition to renewable fuels. With the European Commission recognising Ireland as having the highest potential for renewable gas production per capita in the EU by 2030, the government aims to establish about 150 to 200 anaerobic digestion plants to meet the 2030 target. This ambitious plan underscores Ireland's commitment to a sustainable energy future and requires substantial private investment and clear support mechanisms for developers and investors[17].

[17] *Energy Ireland.2023. Renewable gas: Policy developments and opportunities for biomethane. https://www.energyireland.ie/renewable-gas-policy-developments-and-opportunities-for-biomethane/. Accessed on 30 November 2023.*

3.1 Ireland Decarbonisation Roadmap to 2030

Ireland's Decarbonisation Roadmap to 2030, centered around biomethane, envisions a consumer-led, scalable renewable gas industry that intertwines socio-economic benefits with environmentally responsible production. This roadmap aims to decarbonise sectors with high thermal demands, such as industry and agriculture, while promoting a sustainable and diverse rural bioeconomy. It also focuses on supporting sustainable transport, particularly by decarbonizing heavy goods vehicle (HGV) fuel demand. This approach is aligned with EU and national sustainability and climate action policies and incorporates Green Gas Certification. The roadmap is further strengthened by the Anaerobic Digestion (AD) Charter, which outlines environmental protection and nature-positive measures under development. These efforts mark a significant stride towards meeting national emissions targets and contribute to the broader REPowerEU biomethane goal.

In Ireland, 0.1 billion cubic meters (bcm) of biogases are primarily used for electricity production (76%) in either exclusive electricity or combined heat and power (CHP) plants, with the remaining 24% consumed by the industry (12%) and commercial & public services (12%) (Figure 8)[3]. The 2021 Climate Action Plan initially set a biomethane production target of 1.6 TWh (~0.16 bcm) to be injected into the Natural Gas Grid by 2030. However, this target has been progressively elevated, with the Renewable Gas Forum Ireland (RGFI) proposing a more ambitious 2.5 TWh/year (~0.26 bcm) target, and the Irish Government further increasing the aim to produce up to 5.7 TWh (~0.58 bcm) of biomethane by 2030[18].

The potential for decarbonisation in Ireland's South-East region through renewable gas, particularly biomethane, aligns with the national strategy and is part of Ireland's broader net zero ambitions. The region, with its robust agri-food sector, can significantly contribute to biomethane production, using a range of biomass materials including agricultural wastes. A total of 125 agriculture-based AD plants produce biomethane and fertilizer in Ireland (Island of Ireland)[18]. These plants utilise a variety of sustainable agricultural feedstocks, including mixed species swards, grass silage, sequential cropping, crop residues, and the effective management of animal slurry, marking the approach as practical, and sustainable from technical, commercial, and environmental standpoints.

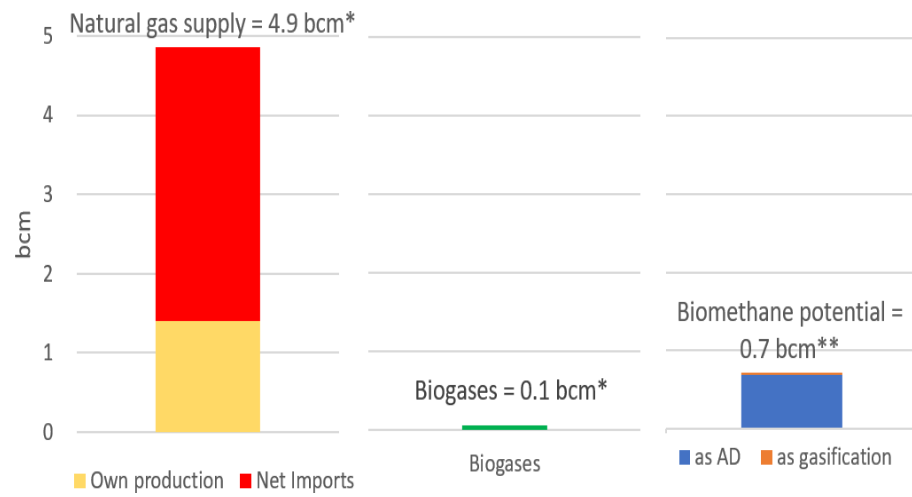


Figure 8. *Comparison of current natural gas supply, biomethane production and potential in Ireland (2021)*[4]

[18] *Renewable Gas Forum Ireland.2022. Roadmap For Renewable Gases in Ireland.* https://www.renewablegasforum.com/wp-content/uploads/2022/06/RGFI-Regatrace_Final-Ireland-Roadmap-20-April-2022-1.pdf. *Accessed on 30 November 2023.*

Here are the main barriers and drivers shown in table 2 in achieving the broader goal of decarbonizing energy systems by 2030.

Table 2. *Barriers and drivers of Decarbonisation Roadmap to 2030*[19]

Main Barriers	Main Drivers
Technological Challenges: • Biomethane production involves complex biological and chemical processes. Advancing these technologies for efficiency and scalability is a challenge. • Capturing and converting biogas to biomethane requires sophisticated and costly technology.	**Climate Change and Environmental Policies:** o Global commitments to reduce greenhouse gas emissions drive the demand for cleaner energy sources like biomethane, i.e., Covenant of Mayor (COM). o Policies aimed at reducing carbon footprints and encouraging renewable energy use can boost biomethane production Climate Action Plan, Renewable Heat Obligation Scheme, National Biomethane Strategy.
Economic Constraints: • High initial investment costs for biomethane production facilities. • Market competitiveness against fossil fuels and other renewable energy sources can be a hurdle due to higher production costs.	**Technological Advancements:** o Innovations in biogas upgrading technologies can reduce costs and improve efficiency. , Development in feedstock processing can expand the sources of biomethane production.
Policy and Regulatory Framework: • Lack of supportive policies or subsidies can impede the growth of biomethane as a renewable energy source. • Regulatory complexities and changing policies can create uncertainties for investors and operators.	**Economic Incentives:** o Subsidies, tax incentives, and financial support from governments can make biomethane projects more viable. o Rising carbon prices can make biomethane more competitive against fossil fuels.
Supply Chain and Infrastructure: • Developing a reliable supply chain for feedstock (organic waste, agricultural residues) can be challenging. • The need for infrastructure development, such as biogas upgrading plants and distribution networks, is a significant barrier.	**Energy Security:** o Biomethane can contribute to energy independence and security by providing a local and stable energy source. o Diversification of energy sources reduces reliance on imported fossil fuels.
Public Perception and Acceptance: • Lack of awareness about biomethane's benefits can affect its acceptance. • Concerns about odor and potential pollution from biogas plants can lead to local opposition.	**Public Awareness and Societal Shift:** o Growing public awareness of environmental issues can increase acceptance and demand for renewable energy. o Shifts in consumer preference towards sustainable and green energy sources can foster a supportive environment for biomethane.

[19] Phelan,P and Vliexs,D. 2023. Increasing the Renewable Energy Share in South East of Ireland. EXPRESS thematic report. South East Energy Agency.

3.2 South-East Region Decarbonisation Roadmap to 2030

The South-East region of Ireland has set ambitious targets for CO2 emission reductions across various sectors as part of its comprehensive climate action strategy. These targets are integral to the region's efforts to contribute to national and international climate commitments, aiming for significant reductions by 2030. Each sector has specific reduction goals, reflecting its unique challenges and opportunities for decarbonisation[20].

Industry Sector

The industry sector in the South-East aims to reduce emissions by 40% by 2030. This target acknowledges the critical role of industrial activities in the regional economy while recognizing the necessity of transitioning to cleaner processes and technologies. Achieving this goal will likely involve energy efficiency improvements, adoption of renewable energy sources, and possibly the implementation of carbon capture and storage (CCS) technologies in high-emission industries.

Transport Sector

Transport emissions are targeted for a reduction of 45% to 60% by 2030. This range reflects the variability and complexity in transforming the transport sector, which is a significant source of emissions. Initiatives may include accelerating the adoption of electric vehicles (EVs), enhancing public transportation networks, and encouraging modal shifts towards more sustainable forms of transport like cycling and walking.

Residential Sector

The residential sector is expected to reduce emissions by 40% to 55% by 2030. Achieving these reductions will require a multifaceted approach, including retrofitting existing housing stock to improve energy efficiency, adopting renewable heating solutions, and ensuring that new constructions are built to high sustainability standards.

Commercial Services

Commercial services are targeted for a 40% to 45% reduction in emissions by 2030. This sector encompasses a wide range of activities, each with its pathways to decarbonization. Strategies may involve enhancing energy efficiency in buildings and operations, integrating smart energy management systems, and transitioning to low-carbon energy sources.

Public Services

The public services sector has the most ambitious target, aiming for a 51% reduction in emissions by 2030. This target aligns with national objectives and underscores the public sector's role as a leader in climate action. Efforts may include greening public infrastructure, adopting sustainable procurement practices, and reducing energy consumption in public buildings and facilities.

Energy System Contributions to CO_2 Emissions

Within the region's energy system, oil and electricity each contribute 33% to CO_2 emissions, highlighting the reliance on fossil fuels and the need for a transition to renewable energy sources. Natural gas,

[20] *Vliexs,D.2021. RE capacities in production and consumption defined for selected partnerships. RegEnergy report. South East Energy Agency.*

contributing 13%, also presents an opportunity for emission reductions, possibly through energy efficiency measures, biogas, and other renewable gases.

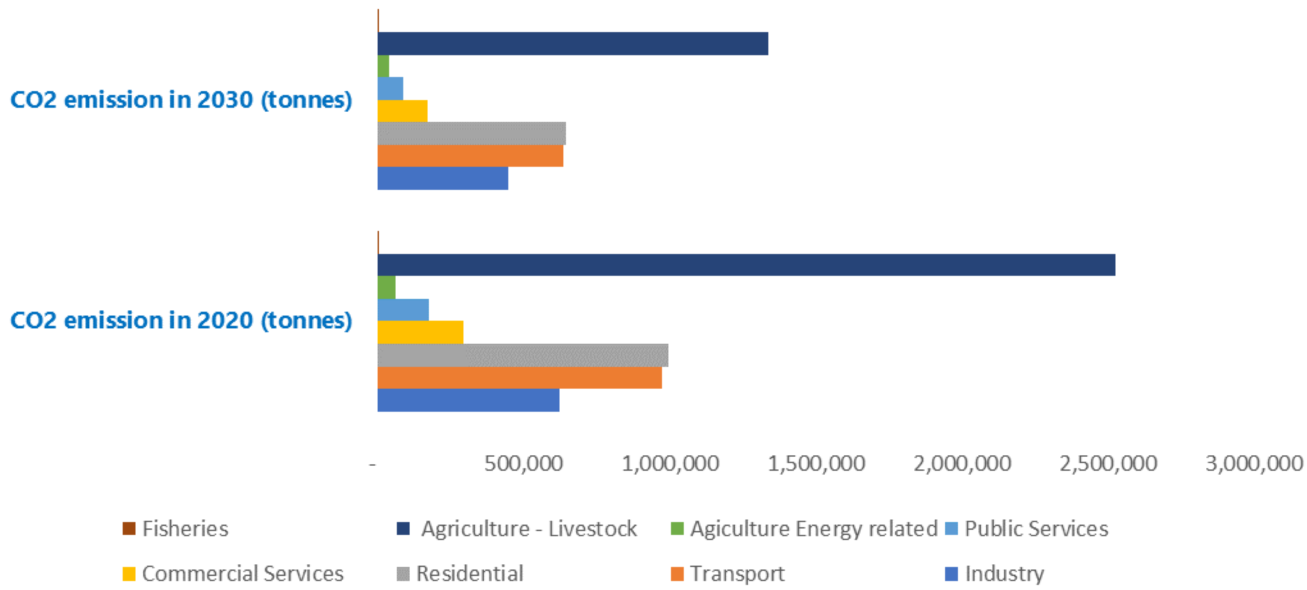


Figure 9. *South-East emission reduction targets by 2030*[20]

The South-East region of Ireland's ambitious emission reduction targets for 2030 across various sectors reflect a comprehensive and integrated approach to climate action (Figure 9). Achieving these targets will require concerted efforts from all stakeholders, significant investments in clean technologies, and supportive policies to facilitate the transition to a low-carbon economy.

Addressing the emissions from these energy sources will be crucial in meeting the overall emission reduction targets. This will likely involve a combination of phasing out oil-based heating systems, increasing the share of renewables in the electricity mix, and improving the energy efficiency of buildings and industrial processes.

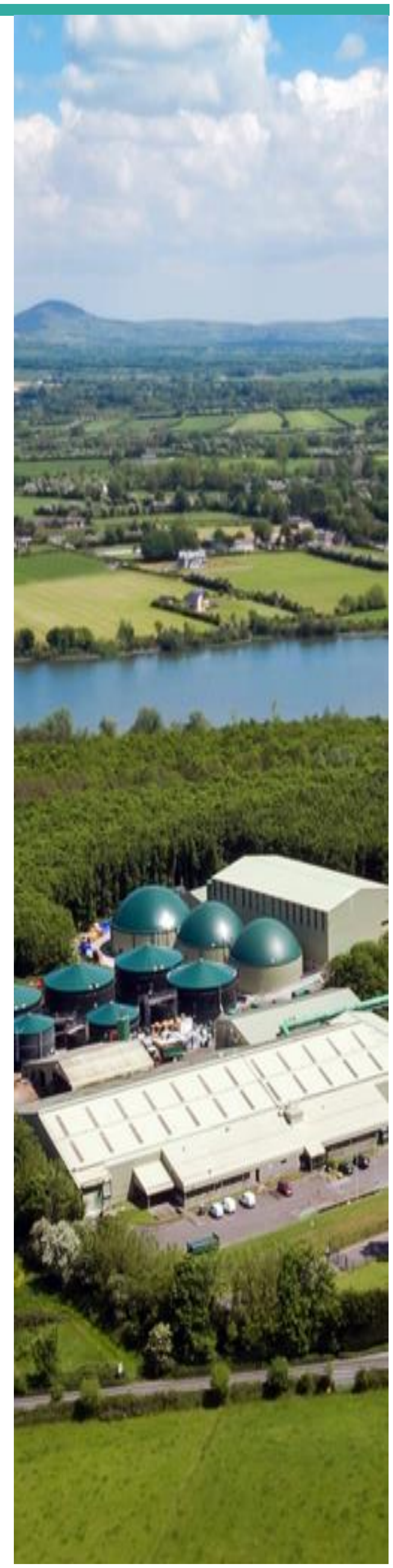
3.3 Ireland Net Zero by 2050

Ireland's pathway to achieving Net Zero by 2050 is significantly supported by the integration of renewable gases like biomethane and hydrogen into its energy system. Biomethane, a carbon-neutral gas derived from farm and food waste via anaerobic digestion, began to be injected into Ireland's gas network in 2019, marking a crucial step towards a cleaner energy future. This process not only supports the decarbonization of key economic sectors but also aids in reducing the country's agricultural emissions, which account for over 35% of its total emissions[21].

The country's Biomethane Energy Report indicates a strong interest from prospective biomethane producers, with potential production reaching 26% of the current gas consumption, which could be integrated into the gas network by 2030. The volume of production anticipated, at 14.8 terawatt-hours (TWh), vastly exceeds the 2030 ambition of 5.7 TWh[21]. Gas Networks Ireland envisions replacing natural gas with renewable gases, including biomethane, to complement intermittent renewable electricity, thereby promoting a cleaner energy future and enhancing energy security through the development of an indigenous biomethane industry.

Having an indigenous source of biomethane will help Ireland reach its Net Zero by 2050 target, as it reduces its reliance on imported fossil fuels, strengthening energy security and making Ireland more resilient to energy shortages. The development of a biomethane industry in Ireland creates new market opportunities include the production and sale of renewable gas for heating and transport, the generation of bio-fertilizers for agriculture, and the commercialisation of biogenic CO2 for industrial use. As these markets expand, they stimulate rural economies, encourage technological innovation, and contribute to a circular economy, all while reducing greenhouse gas emissions and moving Ireland closer to its climate goals.

Biomethane's rapid growth offers a multitude of new market opportunities and significant job opportunities. As the utilisation of biomethane accelerates, it's projected to create approximately over 6,500 jobs by 2030, injecting economic vitality particularly into rural communities[5]. These jobs encompass a broad spectrum of roles, from sustainable agricultural practices for feedstock production to engineering and construction for facility development.



[21] *Gas Network Ireland. 2023. Biomethane Energy Report.* https://www.gasnetworks.ie/docs/business/renewable-gas/biomethane-energy-report.pdf*. Accessed on 18 October 2023*

11% of Ireland's energy is Renewable, and biomass makes up one-third of that.

4.0 Potential Renewable Energy Gas in South-East of Ireland

The potential for renewable energy gas, particularly biomethane, in the South-East of Ireland is substantial and plays a key role in the country's energy future. According to a study by the Sustainable Energy Authority of Ireland (SEAI), renewable gas could provide up to 28% of Ireland's current gas supply by 2050. This is a significant contribution, especially considering the Irish government's ambition to reduce energy-related emissions by 80-95% relative to 1990 levels by 2050[22]. The production of biomethane through Anaerobic Digestion (AD) in agriculture is viewed as a key technology to decarbonise both industry and agriculture while at the same time providing a number of potential ancillary benefits in regard to sustainability and rural development. The South-East region of Ireland (Carlow, Kilkenny, Wexford, and Waterford) is a predominantly rural area with significant bioenergy potential in the form of agricultural land, forestry, and waste residues from municipal, agricultural, and industrial sources. All of these resources can be used to generate heat and electricity in the end-user sectors (building, industry, and transport). South-East region has total area 7,195 km^2 with total population 457,410 (table 3)[23].

Table 3. *South-East region area and population*[23]

County	Population (2022)	Area [km^2]
Carlow	61,968	897
Kilkenny	104,160	2,073
Wexford	163,919	2,367
Waterford	127,363	1,858
Total	**457,410**	**7,195**

The development of these bioenergy resources will contribute to both regional and national security of energy supply and fuel diversity objectives, as well as to reducing carbon dioxide emissions within the region and in Ireland. Biogas and biomethane, generated from materials such as food waste, grass silage, and farm-animal waste through Anaerobic Digestion (AD), offer a viable solution for replacing fossil fuel use in the energy sector. This process also increases the capture of emissions from food and animal waste. The bioenergy resources within the South-East Region of Ireland hold significant potential, particularly in the context of the country's move towards decarbonisation. Ireland has the resources to produce up to 76 Terra-Watt hours (TWh) of heat energy from bioenergy sources, which include agricultural and food-processing by-products, and especially woodchips. This potential exceeds the current Irish heat energy demand of 56 TWh, highlighting the significant role bioenergy could play in meeting the country's energy needs[24].

[22] *SEAI.2017. Assessment of Cost and Benefits of Biogas and Biomethane in Ireland. https://www.seai.ie/publications/Assessment-of-Cost-and-Benefits-of-Biogas-and-Biomethane-in-Ireland.pdf. Accessed on 20 October 2023.*

[23] *Central Statistics Office. 2022. Census of Population 2022. https://www.cso.ie/en/releasesandpublications/ep/p-cpr/censusofpopulation2022-preliminaryresults/geographicchanges/.*

[24] *IrBEA.2021. The Role of Bioenergy in Decarbonising Ireland. https://southeastenergy.ie/the-role-of-bioenergy-in-decarbonising-ireland/. SEAI Energy Show 28-29 April 2021. Accessed on 20 October 2023.*

4.1 Potential Resources for Renewable Gas Production

Biomethane production occurs via two pathways: Anaerobic digestion (AD), which generates biogas and digestate—a nutrient-rich material similar to slurry that provides a local source of nutrients and a greenhouse gas emission mitigation option for land management. The nutrient composition of digestate, including phosphorus (0.2-1.5 kg/t), varies based on the feedstock and is crucial as phosphorus is a critical raw material for the EU. The second pathway is gasification, producing biogas and biochar, a carbon-rich material akin to charcoal, offering a land-based carbon removal solution and soil amendment as per the IPCC (2019). In the South-East Region of Ireland, the potential for biomethane production is notably significant. For instance, Wexford alone has the capacity for a biomethane industry that could produce 394 Gigawatt hours (GWh) of renewable gas, which would contribute to a reduction in carbon emissions by almost 105,000 tonnes annually. The resources for biomethane production in the South-East Region and across Ireland include farm and food waste, which are processed through anaerobic digestion to produce carbon-neutral renewable gas[25]. In the South-East Region of Ireland, the potential resources for biomethane production are diverse and abundant, particularly in the agricultural and municipal sectors:

- ***Agricultural Feedstocks***: These include grass silage, which is a major resource in regions with extensive grassland.
- ***Municipal and Industrial Feedstocks***: Sewage sludge from wastewater treatment plants, food waste from various sources including households and commercial establishments, and fish processing waste, which is rich in organic material, can all be utilized in biomethane production.

4.1.1 Agricultural Feedstocks

With over 80% of Ireland's agricultural land in grassland, the potential for grass resources is substantial. The National Heat Study indicated that the available biomethane grass resource could account for 4-8% of Ireland's current gas fuel demand, potentially rising to 11% by 2030 with changes in livestock management and land usage. The South-East region, comprising Carlow, Kilkenny, Waterford, and Wexford, was the second-largest producer of crops in Ireland, accounting for 20% of domestic production. Livestock waste, such as cattle slurry, pig slurry, and chicken manure, are also significant due to their high organic content, making them excellent for biomethane production.

An analysis of the feasibility of bioenergy implementation plan in the South-East region was conducted by the South-East Energy Agency and XD Consulting for the Interreg North West Europe RegEnergy project in 2022, which identified a range of AD feedstocks with an estimated annual supply of 470 thousand tDM[2]. A total of 137 million Nm3 of biomethane is expected to be produced from these feedstocks, with an annual energy content in excess of 1,306 GWh. A reserve of this size could supply biogas to more than 65 medium-sized AD plants (20 GWh/year) in a farm setting or up to 33 larger (40GWh/year), more likely to be in an industrial setting. The AD feedstock analysis in terms of quantities potentially available, biomethane potential, energy content, and equivalent home heating energy use is shown in table 4.

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[25] *Teagasc. 2022.Developing an Irish Biomethane Industry. https://www.teagasc.ie/news--events/daily/environment/developing-an-irish-biomethane-industry.php#:~:text=Biomethane%20is%20a%20carbon%20neutral,Specialist%20Barry%20Caslin%20gives%20information . Accessed on 20 October 2023.*

Table 4.*Summary AD feedstock analysis*[2]

Anaerobic Digestion Resources	Feedstock potential	Biomethane potential	Energy Potential	Share of regional primary energy use
	(tDM/year)	**(,000 Nm3/year)**	**(GWh/yr)**	**(%)**
Grass Silage	142,867	52,003	520	4.1%
Tillage Crops	160,819	62,151	622	4.9%
Cattle Slurry	84,474	8,154	82	0.6%
Pig Slurry	9,236	1,893	19	0.2%
Chicken Manure	8,644	1,124	11	0.1%
Total Agricultural Feedstocks	**406,040**	**125,326**	**1,253**	**10%**
Domestic Food Waste	4,276	1,035	10	0.1%
Services Food Waste	5,579	1,350	4	0.0%
Manufacturing Food Waste	24,770	5,994	10	0.1%
Municipal WWTP Sludge	5,160	681	7	0.1%
Industrial by-products	24,630	2,169	22	0.2%
Total Municipal & Industrial Feedstocks	**64,415**	**11,230**	**52**	**0.4%**
TOTAL	**470,455**	**136,556**	**1,306**	**10.4%**

a) Grass Silage and Clover Silage

Grass and clover silage are seen as key biomass-based resources for achieving the 5.7 TWh biomethane target by 2030, set as part of the Climate Action Plan 2023[26]. The availability of grass throughout the year makes it a suitable feedstock for biogas production compared to other feedstocks. Due to grass' ability to sequester carbon into the soil matrix, the use of grassland as a renewable source of energy during biogas production offers considerable environmental benefits. The area of pasture in the South-East region represents 11% of the national pasture area. The grass silage potential for AD is assumed in the bioenergy implementation plan study to be achieved by 20% of beef farmers by a 4 tDM/ha/yr incremental increase in yields, on land currently farmed as pasture and silage. In total, 39 thousand hectares of land can be planted with 155 thousand tonnes of dry matter (tDM/yr) of silage each year (tDM/yr). This represents a practical potential of 56 million cubic meters of biomethane per year (Nm3 CH4/year) with an energy content of 562 (GWh/yr)[2].

Silage plays a crucial role in the implementation of Anaerobic Digestion (AD) in the region, accounting for 40% of the total potential. However, its use as a feedstock incurs significant costs. The accessibility of silage is largely dependent on several key factors: its current use as feed for cattle during the winter, potential shifts in local agricultural practices involving diversification of farming operations or

[26] *Teagasc.2023. Agriculture's role in biomethane production. https://www.teagasc.ie/news--events/daily/farm-business/agricultures-role-in-biomethane-production.php. Accessed on 20 October 2023.*

advancements in grassland management, and, crucially, the rate at which farmers are compensated for supplying silage to AD initiatives. Its viability as a raw material for AD is heavily influenced by its price paid to farmers.

b) Tillage crops

The potential of tillage crops in the South-East region of Ireland for biomethane production through Anaerobic Digestion (AD) is significant, particularly under the Climate Action Plan 2023. The successful development of a biomethane AD sector depends on its profitability and the ability to provide confidence to investors and farmers supplying crop feedstocks. Teagasc's research indicates that forage crops capable of high yields with low levels of nitrogen fertilizer, such as red and white clover-based crops, are best suited for AD feedstock requirements[26]. A variety of tillage crops, notably cereals and beets, have been shown to be effective as feedstocks for the process of anaerobic digestion (AD). The 2020 National Farm Survey - Sustainability Report highlights a significant challenge, revealing that 45% of tillage farms are struggling with viability[27]. This situation presents an opportunity to encourage these farmers to diversify into AD crop production. The proposal is that dedicating 20% of the land used for traditional tillage to grow a rotational mix of crops such as beet, winter rye, spring cereals, and triticale for AD could lead to considerable gains. This approach is estimated to offer a technical potential of 161 thousand tons of dry matter annually. From this, it's possible to produce 62 million cubic meters of biomethane every year, translating to an energy yield of 622 GWh per year.

c) Animal Slurry

The utilisation of winter slurry from cattle, which represents approximately 20% of all winter cattle slurry produced in Ireland, is another significant resource. For effective biomass production, an equal mix of grass silage and slurry is assumed. Approximately 120,000 hectares of land, less than 3% of the available land area, is required to meet the feedstock needs for anaerobic digestion (AD) plants[27]. This analysis considers three animal types that have been identified as generally suited to anaerobic digestion: cattle, pigs, and poultry (table 5)[2].

Table 5. *The population of cattle, pigs, and poultry in the South-East region[2]*

	Number of Cattle	Number of pigs	Number of poultry
Carlow	106,861	23,721	4,288
Kilkenny	373,951	53,530	29,385
Waterford	270,583	104,530	660,918
Wexford	301,601	82,316	10,112
South-East region	**1,052,996**	**264,097**	**704,703**

[27] *Teagasc.2021. National Farm Survey 2020 result. https://www.teagasc.ie/media/website/publications/2021/Teagasc-National-Farm-Survey-2020.pdf. Accessed on 20 October 2023*

Data from the Central Statistics Office (CSO) 2020, reveals the population of cattle, pigs, and poultry in the South-East region, with an assumption that 10% of cattle slurry, 75% of pig, and 22% of poultry waste are available for processing in an AD plant[28]. The importance of this data lies in its utility for planning and resource management, especially in the context of sustainable waste processing practices. An interesting aspect of this data is the assumption regarding the waste from these livestock populations that can be processed in an Anaerobic Digestion (AD) plant: 10% of cattle slurry, 75% of pig waste, and 22% of poultry waste. Anaerobic Digestion (AD) is a process that breaks down organic materials in the absence of oxygen, producing biogas that can be used for energy and a nutrient-rich digestate that can be used as a fertilizer.

Figure 10 below provides a dual perspective on the livestock populations in the South-East region and the potential waste available for processing in an Anaerobic Digestion (AD) plant. On one side, the bar graphs represent the total number of cattle, pigs, and poultry in each region. On the other side, depicted by lines with markers, is the estimated waste from each livestock type that could be utilized for AD processing, based on the assumptions provided (10% of cattle slurry, 75% of pig waste, and 22% of poultry waste).

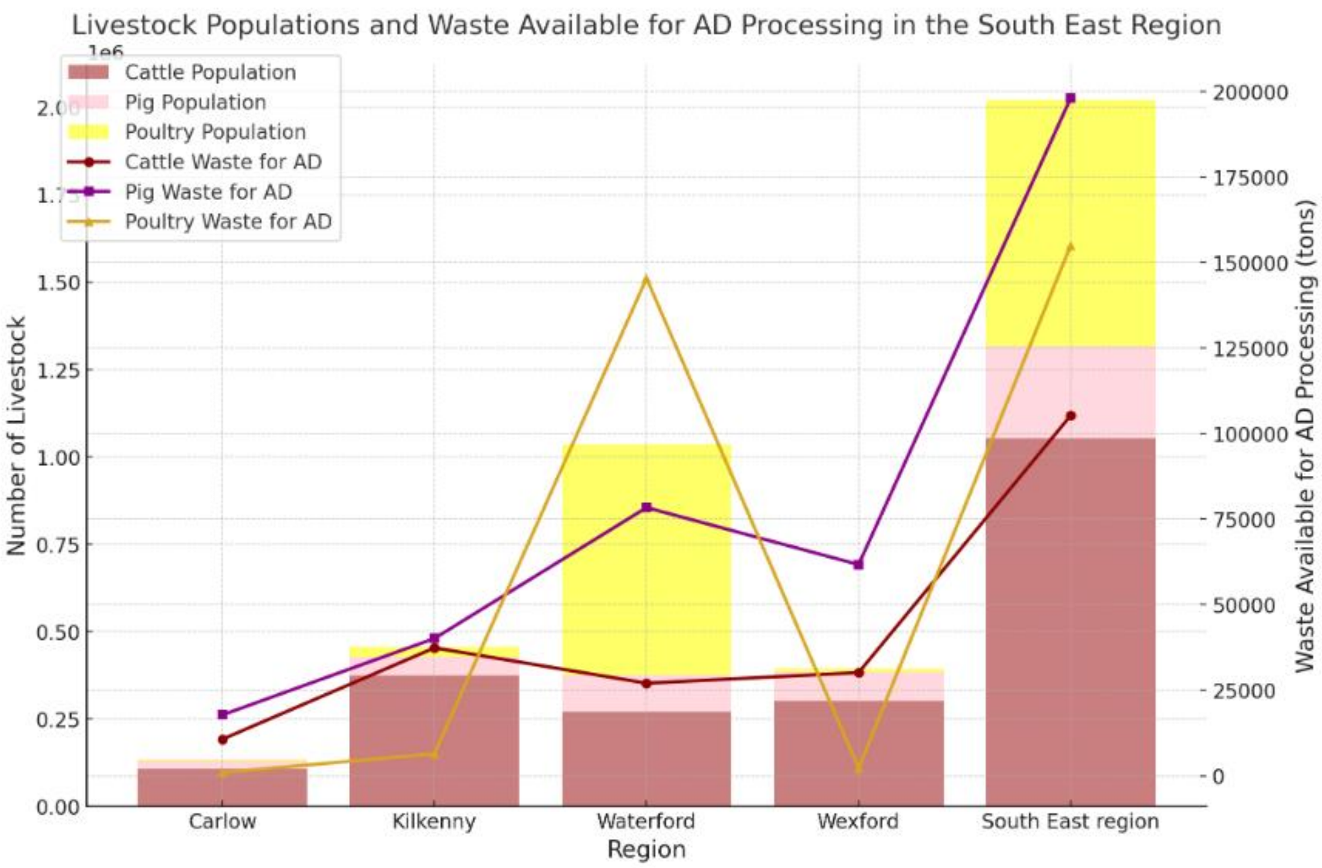

***Figure 10**. Potential livestock waste for AD processing*[19]

[28] *CSO.2020. Census of Agriculture 2020 - Preliminary Results.* https://www.cso.ie/en/releasesandpublications/ep/p-coa/censusofagriculture2020-preliminaryresults/livestock/*. Accessed on 30 November 2023*

The estimation of available cattle slurry for biogas production incorporates 2020 census data on cattle numbers, combined with Teagasc's study on slurry production rates by cattle type (in tonnes of fresh weight), factoring in a 10% methane loss during storage[26]. The storage duration of waste, which can affect gas yields, means that slurry availability fluctuates seasonally. Consequently, it's estimated that around 394 thousand tons of dry matter (tDM) of cattle slurry per year are available for Anaerobic Digestion (AD). This translates to a technical potential of producing 47 million cubic meters of biomethane annually, with an energy output of approximately 473 GWh per year. As per the 2020 National Farm Survey, Ireland had 1.6 million pigs, indicating a significant number of these animals in the country[27]. Pig slurry, like other animal waste, can be a valuable resource for biomethane production through anaerobic digestion.

The potential for biomethane production from pig slurry would depend on factors such as the amount of waste produced per animal, the efficiency of the AD process, and the specific characteristics of the slurry. In general, the high organic content in pig slurry makes it a suitable feedstock for AD, potentially contributing to renewable energy targets and providing an alternative waste management solution for pig farms. A total of 264 thousand pigs resides in the area, producing approximately 250 thousand m3 of slurry per year (9,236 tDM/yr), with a potential biomethane production of 1.9 million Nm3/year and an energy production of 19 GWh.

The potential for biomethane production from poultry manure would depend on various factors, including the quantity of waste produced per bird, the efficiency of the AD process, and the specific characteristics of the manure. Given the high organic content in poultry manure, it is likely a suitable feedstock for AD, contributing to renewable energy targets and offering an alternative waste management solution for poultry farms. Poultry manure, gathered either as litter or from pits in broiler and layer poultry sheds, presents notable biomethane potential.

The estimated annual methane potential from raw biogas produced by cattle, pigs, and poultry in this study is around 68 GWh (table 6). Representing 0.5% of the region's total energy demand, this animal slurry-derived biogas could serve as a hydrogen source for transportation corridors linking major urban areas, simultaneously offering economic opportunities for rural regions. The amount of hydrogen generated from this biogas would be approximately 53 tonnes[2].

Table 6. *Potential Hydrogen production from animal Slurry[2]*

		Cattle		Pig		Poultry	
Number of livestock		**factors**	1,052,996	**factors**	264,097	**factors**	704,703
Slurry	**tonne**	1.07	1,126,706	0.12	31,692	0.011	7,590
No. week inside		16	346,679	52	31,692	52	7,590
availability		10%	34,668	75%	23,769	22%	1,670
Biogas produced	**m3**	250	8,666,967	250	5,942,183	200	333,945
Biogas produced	**GJ**	0.024	208,007	0.024	142,612	0.024	8,015
Biogas produced	**GWh**	277.8	57.784	277.8	39.618	277.8	2.226
Hydrogen produced	**Kg**	3.295	0.855	3.295	0.489	3.295	0.003
Hydrogen produced	**GWh**	39	33.06	39	19.05	39	0.130
Total Hydrogen potential	**52.240 GWh**						

4.1.2 Municipal and Industrial Feedstocks

In 2021, Ireland generated 3.17 million tonnes of municipal waste, with 41% being recycled. Out of the recycled waste, 824,969 tonnes went for material recycling, and 487,594 tonnes were used for composting/anaerobic digestion, marking a 39% increase from 2020 in the latter category[29]. This suggests a growing trend in utilising organic waste for biomethane production through anaerobic digestion processes.

i. Organic Waste

Organic waste holds significant potential for biogas production through the process of anaerobic digestion (AD). This process involves the breakdown of organic matter, such as food waste, agricultural residues, and animal manure, in the absence of oxygen. The bacteria involved in AD produce biogas, primarily composed of methane and carbon dioxide. It is estimated that in the South-East region, there are 34.6 thousand tDM/year of residential and non-residential food wastes available, with a biomethane potential of 8.4 million Nm3 per year. Based on the assumption that 80 percent of the waste collected can be processed in an AD plant, approximately 55 GWh of biogas could be produced, which is equivalent to 26.16 GWh of hydrogen (table 7)[30].

Table 7. *Hydrogen production from organic waste*[30]

	Unit	Organic waste	
Organic Waste availability	tonne		80,098
Organic Waste collection	tonne	Factor 80%	64,078
Total biogas potential	GWh	852.74	54.642
Hydrogen potential	kg	3.295	670,730
Hydrogen potential	GWh	39	26.16

ii. Sewage sludge

Sewage sludge is the residual, semi-solid material that is produced as a by-product during the treatment of wastewater in sewage treatment plants. It is organic in nature, containing a mix of water, organic matter (such as human waste, food scraps, and soap), bacteria, and nutrients. The potential for municipal sewage sludge to become biomethane is considerable, as evidenced by a project undertaken to enhance biogas production from such waste. Ireland's potential for converting municipal sewage sludge into biomethane is significant for several reasons:

1. ***Waste Management***: Ireland, like many countries, is continuously seeking more sustainable ways to manage waste. Converting sewage sludge into biomethane offers a dual solution of reducing waste volumes and producing renewable energy.
2. ***Renewable Energy Goals***: Ireland has ambitious renewable energy targets to reduce greenhouse gas emissions and increase the share of renewables in its energy mix. Biomethane from sewage sludge can contribute to these targets by providing a renewable source of energy for heating, electricity, and transportation.

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[29] *EPA.2021. Municipal waste statistics for Ireland.* https://www.epa.ie/our-services/monitoring--assessment/waste/national-waste-statistics/municipal/#:~:text=In%202021%2C%20Ireland%20generated%203,41%20per%20cent%20of%20it. *Accessed 5 December 2023.*
[30] *Malik,K.2021. Green Hydrogen resources in South East Region. Report. South East Energy Agency.*

3. ***Agricultural Sector***: Ireland's strong agricultural sector produces significant amounts of organic waste, which can be co-digested with sewage sludge in AD plants, enhancing the overall efficiency of biomethane production.

4. ***Energy Security***: Producing biomethane locally from sewage sludge can reduce Ireland's dependence on imported fossil fuels, enhancing energy security and supporting local economies.

5. ***Environmental Benefits***: Converting sewage sludge to biomethane can significantly reduce methane emissions from waste management processes. Methane is a potent greenhouse gas, and its capture and use as a fuel can contribute to climate change mitigation efforts.

There are 6,406 tonnes of dry sludge (TDS) collected in wastewater treatment plants in the South-East region. It is estimated that an additional 1,199 tonnes can be collected from domestic WWTPs adding up to a total of 7,605 tonnes (table 8)[2].

Table 8. *Sewage sludge collected in South-East region[2]*

	Sludge load per from WWTPS [t]	Total Load [t]
Carlow	1,066	1,208
Kilkenny	1,407	1,710
Wexford	2,071	2,589
Waterford	1,862	2,098
Total	**6,406**	**7,605**

There is a potential production of 6.5 GWh of biomethane from the sewage sludge on an annual basis, and when that biomethane is converted into hydrogen, it is approximately 4.83 GWh of hydrogen (table 9). Under the existing wastewater sludge management strategy, there are presently no facilities equipped to harvest biogas from wastewater treatment plants.

Table 9. *Renewable gas production from sewage sludge[2]*

	Unit	Sludge load per from WWTPS
Available Sludge	Tonne	6,406
Biogas Produced	GWh	11.7
Biomethane produced	Kg	408,382
Hydrogen produced	GWh	4.83

While the potential is significant, there are also challenges to be considered, including the need for investment in AD infrastructure, ensuring the quality of sewage sludge for AD processing, and navigating regulatory and market mechanisms for biomethane. However, with supportive policies, technological advancements, and stakeholder engagement, the conversion of municipal sewage sludge to biomethane can play a key role in Ireland's transition to a more sustainable and circular economy.

iii. Industrial Food Waste

Organic waste and liquid by-products from food processing, including those from milk, fish, and meat processing, can be transformed into biogas in anaerobic digestion (AD) plants. Currently, this type of waste is usually disposed of through land spreading. It's estimated that the total amount of industrial food processing waste in Ireland is around 441,000 tonnes. However, due to limited information, this waste is presumed to be evenly distributed among the Irish population. Therefore, it is estimated that there are about 37,955 tonnes of industrial food waste in South-East region.

The overall potential for methane and hydrogen production from industrial food waste, while marginally lower than other biogas sources evaluated, remains a notable source. According to table 9, the total annual methane potential in raw biogas derived from industrial food waste is estimated to be approximately 17.259 GWh. This equates to around 13.55 GWh of hydrogen production annually (Table 10)[2].

Table 10. *Potential biogas and hydrogen production from food waste[2]*

South-East region Data	Unit	Industrial food waste
Industrial food waste resources	tonnes	37,955
Industrial food waste availability	tonnes	12,652
Biogas production	GWh	17.259
Hydrogen production	GWh	13.552

iv. Landfill

Landfills, specifically designated areas for waste disposal, handle a variety of refuse including product packaging, food remnants, bottles, furniture, appliances, and yard waste. This waste may originate from homes, industries, or commercial sources. The volume of waste sent to landfills fluctuates based on practices in reuse, composting, and recycling. Biogas produced in landfills, often referred to as landfill gas, results from the digestion process occurring underground rather than in an anaerobic digester. From the perspective of this study, landfills are identified as significant potential sources of methane and hydrogen. The total estimated annual potential of biogas from landfills is about 47.8 GWh, which could translate to approximately 35.18 GWh of hydrogen if converted (table 11)[2].

Table 11. *Renewable gas production from landfill in South-East Region[2]*

Location recycling and waste disposal	Location, County	Methane extracted [t]	Energy content [GWh]
Dunmore recycling and waste disposal	Dunmore, Kilkenny	170.468	2.625
Powerstown Landfill and Recycling Centre	Powerstown, Carlow	538.740	8.297
Holmestown Waste Management Facility	Barntown, Wexford	28.432	0.438
Killurin Landfill Site	Killurin, Wexford	729.560	11.235
Kilbarry Landfill Site	Kilbarry, Waterford	612.146	9.427
Dungarvan Waste Disposal Site	Dungarvan, Waterford	1,022.200	15.742
Total Biogas potential		3,101.546	47.764
Total Hydrogen potential			35.178

4.2 Harnessing Renewable Gas Capabilities in South-East Region

4.2.1 Exploring the Potential Applications of Biogas

The potential for biogas usage in Ireland is substantial and is being increasingly recognised as a key component in the country's transition to a low-carbon energy future. Currently, Ireland has the potential to be a leader in biomethane production, despite a slow start in developing anaerobic digestion (AD) plants. With rapid expansion, biomethane could replace up to 20% of Ireland's current natural gas demand by 2030.

In the South-East region of Ireland, the potential for biogas production is closely tied to the availability and type of feedstock in the region. Given the agricultural profile of this region, feedstocks such as grass silage, agricultural residues, and animal manures are abundant, which are key resources for biogas production. The potential for biogas generation in this area is substantial, largely due to the prevalence of these feedstocks.

The efficient utilisation of grass silage, in particular, plays a significant role, as it has been identified as having the highest potential among the available feedstocks. The production potential from grass silage alone stands out, contributing a significant portion to the region's overall biogas potential. When other feedstocks are factored in, along with improvements in feedstock management and biogas technology, the South-East region of Ireland shows a promising capacity for biogas production that could contribute significantly to its energy needs. As shown in figure 11 below, the potential biogas production for grass silage at 25% availability is similar to that for other feedstocks at 100% availability[20].

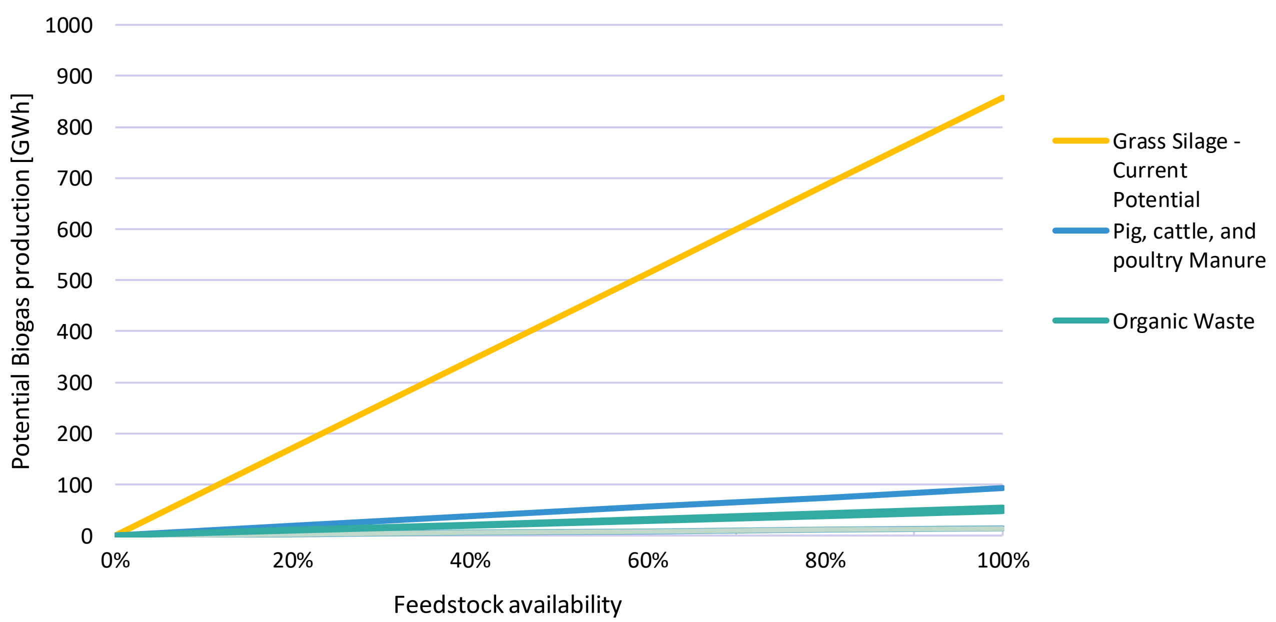

Figure 11. *Biogas production by feedstock availability*[20]

Biogas can be converted into biomethane through an upgrading process. The diverse applications of biogas and their relative effectiveness compared to the energy demands in various sectors are detailed in the following table 12. It is postulated that biogas could serve as a heat source or be used in a CHP system with an overall efficiency of 82% (comprising 32% electricity and 50% heat generation)[2]. When upgraded to biomethane, it is estimated to incur a methane loss of about 2%.

Table 12. *Share of energy demand per biogas end use*[2]

	Biogas		Electricity - CHP		Heat - CHP		Biomethane	
	Potential Production GWh	Share of thermal demand	Potential Production GWh	Share of electrical demand	Potential Production GWh	Share of thermal demand	Potential Production GWh	Share of transport demand
Grass Silage - Current Potential	857.3	16.5%	274.3	10.4%	428.7	8.3%	840.2	19.3%
Grass Silage - Future average Potential	3,563.7	68.7%	1,140.4	43.3%	1,781.9	34.3%	3,492.4	80.3%
Grass Silage - Future maximal Potential	6,656.7	128.3%	2,130.2	80.9%	3,328.4	64.1%	6,523.6	150.1%
Pig, Cattle and Poultry Manure	92.9	1.8%	29.7	1.1%	46.5	0.9%	91.0	2.1%
Organic Waste	54.6	1.1%	17.5	0.7%	27.3	0.5%	53.5	1.2%
Sewage Sludge	13.9	0.3%	4.5	0.2%	7.0	0.1%	13.7	0.3%
industrial Food Waste	13.6	0.3%	4.3	0.2%	6.8	0.1%	13.3	0.3%
Landfill	47.8	0.9%	15.3	0.6%	23.9	0.5%	46.8	1.1%
Total - Current Potential	1,080.1	20.8%	345.6	13.1%	540.1	10.4%	1,058.5	24.4%
Total - Future average Potential	3,786.5	73.0%	1,211.7	46.0%	1,893.3	36.5%	3,710.8	85.4%
Total - Future average Potential	6,879.6	132.6%	2,201.5	83.6%	3,439.8	66.3%	6,742.0	155.1%

4.2.2 Exploring the Potential Applications of Hydrogen

Ireland's potential for hydrogen production is significantly influenced by its abundant natural resources and economic activities. The country's extensive agricultural sector provides a substantial amount of biomass, which can be efficiently converted into biohydrogen through various processes like gasification or pyrolysis. This advantage positions Ireland favorably in the realm of biohydrogen production. In addition to agricultural biomass, Ireland has the capacity to utilize organic waste materials, including both municipal and industrial waste, for hydrogen production. Techniques such as anaerobic digestion are instrumental in this regard, offering a sustainable method to transform waste into valuable energy resources. Although natural gas reforming is a non-renewable method, it currently plays a crucial role in global hydrogen production. For Ireland, this method could act as a bridge towards more sustainable hydrogen production techniques in the future. The success and scalability of hydrogen production in Ireland are contingent upon the effective integration of these varied feedstock sources, advancements in relevant technologies, and strategic energy planning that aligns with the nation's environmental and economic goals.

In the South-East region, it is estimated that the various feedstocks currently available can potentially supply around 727 GWh of Hydrogen, as detailed in Table 13. This figure accounts for approximately 5.8% of the total energy demand in the region. However, this potential could significantly increase to about 4,913 GWh, or 39% of the region's overall energy demand, with improved land and livestock management practices. Among the available feedstocks, grass silage holds the highest potential, currently fulfilling 79% of the region's potential for hydrogen production[30].

Table 13. *Potential Hydrogen share of the overall energy demand*[30]

	Hydrogen	
	Potential Production [GWh]	**Share of overall energy demand in South-East Region**
Grass Silage - Current Potential	618.78	4.97%
Grass Silage - Future average Potential	2572.18	20.67%
Grass Silage – Maximal Potential	4804.64	38.62%
Pig, cattle, and poultry Manure	49.36	0.40%
Organic Waste	39.44	0.32%
Sewage Sludge	7.29	0.06%
Industrial Food Waste	12.46	0.10%
Landfill	35.18	0.28%
Total - Current Potential	**727.32**	**5.85%**
Total - Future average Potential	**2680.73**	**21.55%**
Total – Future maximal Potential	**4913.19**	**39.49%**

The exploration of hydrogen production in the South-East region of Ireland, particularly through the utilisation of grass silage as a feedstock, presents an intriguing case for renewable energy development. When considering a 10% availability rate for grass silage, its potential for hydrogen production can be compared favorably to that achievable using other types of feedstock, even when those alternatives are available at a 100% rate. This comparison underscores not only the high energy potential inherent in grass silage but also the efficiency and effectiveness of utilizing locally available agricultural residues for sustainable energy production.

Grass silage, a preserved form of grass crop, is abundant in the South-East region of Ireland due to its conducive climate and well-established agricultural practices. The process of converting grass silage into hydrogen typically involves biochemical processes like dark fermentation or thermochemical processes such as gasification, followed by steam reforming. Despite the assumed 10% availability rate, which accounts for constraints such as seasonal variations, competing uses, and logistical challenges, grass silage remains a compelling feedstock due to its high biomass yield and energy content. Figure 12 shows the potential hydrogen production relative to the availability of feedstock.

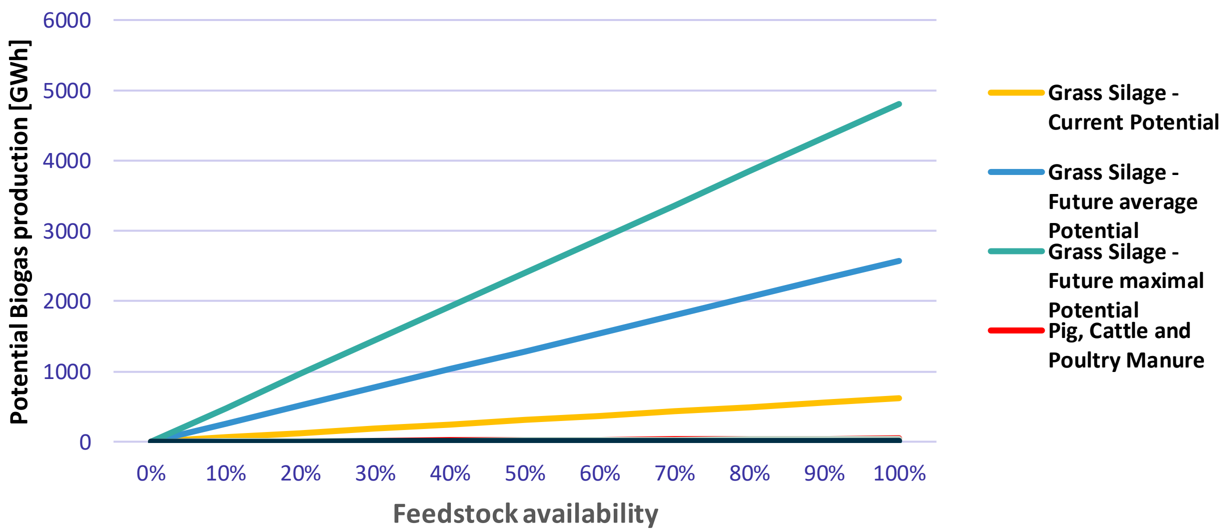

Figure 12. *Hydrogen production by feedstock availability*[30]

Comparative Potential with Other Feedstocks

The potential for hydrogen production from grass silage, even at a reduced availability rate, compares favourably with other feedstocks for several reasons:

1. **Energy Density**: Grass silage has a considerable energy density, which makes it an efficient source of biomass for hydrogen production. Even at a 10% availability rate, the sheer volume of grass silage that can be harvested in the South-East region of Ireland ensures a substantial input for hydrogen production processes.
2. **Sustainability**: Utilizing grass silage aligns with sustainable energy production principles, as it is a renewable resource that can be replenished annually. It also contributes to the circular economy by adding value to agricultural by-products.
3. **Local Availability**: The local availability of grass silage reduces transportation costs and associated emissions, enhancing the overall sustainability of the hydrogen production process. This local approach to energy production fosters regional energy independence and resilience.

4. **Comparative Efficiency**: When compared to other feedstocks that might be available at a 100% rate, grass silage can offer comparable, if not superior, hydrogen production potential. This is particularly true when considering the full lifecycle emissions and energy inputs of alternative feedstocks, including their cultivation, harvest, processing, and transportation.

Challenges and Opportunities

The exploration of hydrogen production from grass silage in the South-East region of Ireland presents a blend of challenges and opportunities that reflect both the pioneering spirit of renewable energy innovation and the pragmatic considerations of agricultural and energy sectors.

Challenges:

1. ***Technology and Efficiency:*** The technology for converting grass silage to hydrogen is complex. Achieving a process that is both efficient and economically viable on a large scale is a significant challenge.
2. ***Infrastructure Investment:*** Establishing a supply chain for hydrogen, including production facilities, storage, and distribution networks, requires substantial upfront investment.
3. ***Market Development:*** Hydrogen fuel markets are in their nascent stages. Developing demand, alongside production capabilities, is crucial for the sustainability of the industry.
4. ***Regulatory Environment:*** Establishing a clear and supportive regulatory framework is essential to foster the growth of a hydrogen economy and to ensure safety and environmental standards.
5. ***Public Acceptance and Education:*** Gaining public support is vital for the success of hydrogen as an alternative fuel. This involves educational initiatives to demonstrate the benefits and safety of hydrogen.
6. ***Competition for Raw Materials:*** As the demand for renewable energy sources grows, there may be competition for grass silage between different energy production processes, such as biomethane generation, which could influence supply and pricing.

Opportunities:

1. ***Abundant Resource***: The South-East region of Ireland, with its rich agricultural land, produces a significant amount of grass silage. This abundance presents an opportunity to utilize a local, renewable resource for sustainable hydrogen production.
2. ***Environmental Benefits:*** Hydrogen produced from grass silage is a clean fuel; its use can significantly reduce greenhouse gas (GHG) emissions compared to fossil fuels, contributing to Ireland's climate action goals.
3. ***Energy Diversification:*** Developing hydrogen production from grass silage contributes to a more diversified and resilient energy portfolio for Ireland, reducing dependency on imported fuels.
4. ***Rural Development and Job Creation:*** Localized hydrogen production can stimulate economic growth in rural areas, creating jobs in both the setup and operation of hydrogen production facilities.
5. ***Agricultural Sector Integration:*** This initiative can offer farmers and the agricultural sector an additional revenue stream, promoting the circular economy through the valorization of agricultural by-products.

While the potential for hydrogen production from grass silage in the South-East region of Ireland is marked by significant opportunities, especially for environmental sustainability and regional development, it is also fraught with challenges that require strategic planning, technological innovation, and supportive policies to overcome.

4.3 Sustainable Biomethane Production in South-East Region

Sustainable biomethane production is increasingly pivotal in Ireland's renewable energy strategy and carbon emission reduction efforts, despite the nation's biomethane industry being less developed compared to other EU members. Currently, biomethane makes a minimal contribution to Ireland's energy mix, with urban areas primarily relying on natural gas. However, renewable biogas holds potential to replace fossil natural gas, significantly aiding in Ireland's decarbonisation. Notably, Ireland boasts the highest per capita potential for biomethane production in the EU, offering an exceptional opportunity to cultivate a robust indigenous biomethane sector. This development is supported by the Renewable Heat Obligation, which, if enacted, will further support biomethane production at scale.

Biomethane production through anaerobic digestion (AD) in Ireland is an emerging component in the country's renewable energy landscape, aimed at reducing carbon emissions and transitioning towards cleaner energy sources. This process involves converting farm and food waste into biomethane, a carbon-neutral gas. Despite its current underdevelopment compared to other EU countries, Ireland shows immense potential for biomethane production per capita. The Irish government, recognizing this potential, is investing in the expansion of AD facilities with targets set for significant growth by 2030.

Approximately 84% of the total biogas produced was generated by anaerobic digestion (AD). The AD process consists of microorganisms breaking down organic matter without oxygen to produce biogas and digestate. Farm scale AD systems typically use manure, slurries, vegetable wastes, or imported materials such as draff and distillery waste as feedstocks[31]. Various technologies are available for an AD installation, depending on the feedstock available, the scale of the plant, and the local climate. Wet systems will be more appropriate in Ireland, although crops, which form most of the feedstock, could be relatively dry and at the high end of dry matter content. It is imperative for AD facility operators to ensure that the conditions are suitable for all microbial communities. The primary microbial communities are fermentation bacteria, acetogens, and methanogens. There are four stages involved in the microbial breakdown process or digestion (Figure 13):

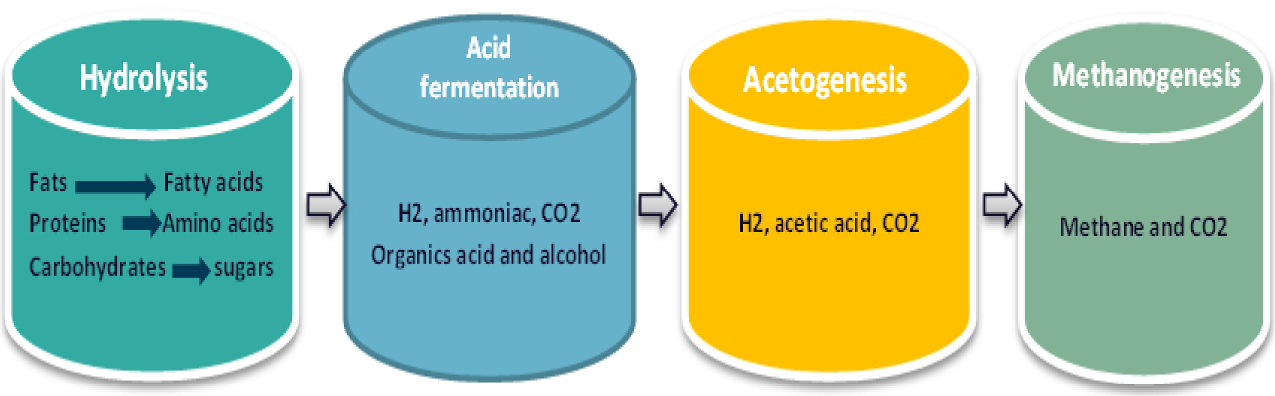

Figure 13. *Four stages digestion process in AD biomethane* [31]

[31] *FAS. 2018. Anaerobic Digestion (AD) – Farm Scale, https://www.fas.scot/downloads/tn698-anaerobic-digestion-ad-farm-scale/. Accessed on 30 November 2023*

A SWOT analysis outlines the multi-dimensional aspects of initiating and sustaining biomethane production in South-East Ireland, considering the region's unique characteristics and broader energy and environmental context.

SWOT Analysis Biomethane production in South-East region

Strength:

- **Rich Agricultural Source:** The region's strong agricultural sector provides abundant raw materials, such as livestock manure and crop residues, essential for biomethane production.
- **Existing Infrastructure:** The presence of farming and food processing infrastructure can be adapted or extended for biomethane production and distribution.
- **Government Support:** Potential for government incentives and support in line with Ireland's renewable energy targets and carbon reduction commitments.
- **Technological Expertise:** Availability of technical expertise in agriculture and renewable energy within local universities and research institutions.

Weakness:

- **Initial Capital Investment:** High initial costs for setting up AD plants and necessary infrastructure could be a barrier.
- **Market Development:** The biomethane market in Ireland is still in its nascent stages, requiring significant efforts in market development and consumer education.
- **Regulatory Challenges:** Navigating the regulatory landscape for renewable energy can be complex and time-consuming.
- **Dependency on Feedstock Supply:** The success of biomethane production is highly dependent on a consistent and reliable supply of organic waste materials.

Opportunities:

- **Energy Independence:** Biomethane production can contribute significantly to regional energy self-sufficiency and reduce dependency on imported fossil fuels.
- **Environmental Benefits:** It aligns with environmental goals, offering a cleaner, renewable energy source and aiding in waste management.
- **Economic Development:** Potential for job creation and economic stimulation in rural areas through new biomethane facilities.
- **Innovation and Research:** Opportunities for local innovation in biomethane technology and collaboration with academic and research institutions.

Threats:

- **Market Fluctuations**: Vulnerability to changes in energy prices and market demand for renewable energy.
- **Policy Changes**: Potential shifts in government policies and subsidies that could impact the viability of biomethane projects.
- **Technological Advancements**: Rapid advancements in alternative renewable energy technologies could outpace biomethane.
- **Environmental Regulations**: Stricter environmental regulations could increase the operational costs or limit the scale of production.

The biogas market in Ireland is in a growth phase, driven by the country's commitment to renewable energy and sustainability.

5.0 Irish Market Opportunity for Biogas

The market opportunity for biogas and biomethane in the South-East region of Ireland is substantial and is expected to grow significantly in the coming years. Gas Networks Ireland highlights the potential to replace over 25% of the natural gas in their network with biomethane, which could lead to new income streams for the agricultural sector. Presently, the national gas network meets more than 30% of Ireland's energy needs, including 40% of all heating and nearly half of the electricity generated. In 2020, Gas Networks Ireland introduced domestically produced biomethane into the network, with 41 gigawatt-hours of biomethane transported through the national network in the previous year. This initiative aligns with the government's target of 5.7 TWh of biomethane production by 2030, an achievable goal given the right supportive structures and policies.

The development of the biomethane market is crucial for Ireland's energy independence. A key factor in this development is the introduction of a renewable heat obligation scheme by the government, which would require fuel suppliers in the heat sector to include a certain proportion of renewable sources like biomethane. This scheme is expected to encourage the use of indigenously produced biomethane from waste and agricultural feedstocks, considered the lowest cost renewable fuel source available to suppliers. As of 2019, emissions from the heat sector accounted for 12.6 million tonnes of carbon equivalent, with agriculture accounting for 4% of this. Ireland aims to meet net zero emissions by 2050, and the development of the biogas market, including biomethane, is seen as a critical component in achieving this goal[32].

Compared with utilisation of waste feedstocks, the AD feedstocks and Exploratory scenarios result in higher silage costs and reduced carbon savings. A high biomethane production cost from gasification plants further escalates the net cost in the exploratory scenario. While increased biomethane will reduce GHG by 80-95% by 2050, these two scenarios deliver far more renewable energy and carbon savings. AD plants can generate income from the following sources[33]:

1. Export of electricity from combined heat and power (CHP) installations
2. Using imported electricity to offset imported energy normally results in greater savings than export rates.
3. Payment of generation tariff (i.e., the FIT scheme)
4. Payment of renewable heat incentive (RHI) from eligible heat use.
5. Using a biogas boiler or recovery of heat from a CHP installation will reduce the amount of imported heating fuel.
6. Export of heat from biomass boilers or CHP installations to third parties

There are several Support Schemes available in Ireland for biogas production: Sustainable Energy Authority (SEAI) support schemes, Biofuels Obligation Scheme, Sustainable Support for Renewable Heat (SSRH), Excellence in Energy Efficient Design (Exceed), Project Assistance Grant (PAG). Climate Action Fund (CAF), Renewable Electricity Support Scheme (RESS), Enterprise Ireland Commercial Case Feasibility Grant, Clan Credo – Community Climate Action programs, Community Finance Ireland,

[32] *Irish Farmer Journal. 2021. Irish biogas market to develop by 2023. https://www.farmersjournal.ie/irish-biogas-market-to-develop-by-2023-642126. Accessed in October 22, 2022*

[33] *SEAI.2022. National Heat Study, Net Zero by 2050. https://www.seai.ie/publications/National-Heat-Study-Summary-Report.pdf. Accessed October 30,2022.*

Energy Efficiency Obligation Scheme (EEOS), European Local Energy Assistance (ELENA), European Regional Development Fund (ERDF), EPA – Green Enterprise, Rural Economic Development Zone (REDZ), Targeted Agricultural Modernisation Schemes (TAMS), and Accelerated Capital Allowance (ACA).

During the development of the National Biomethane Strategy, various support mechanisms, including Feed-in Tariffs (FiT) and Contracts for Difference (CfD), were evaluated. To rapidly stimulate the industry, the Renewable Heat Obligation combined with Capital Grants was chosen to support the biomethane sector in Ireland, providing budget certainty and facilitating sector growth. This approach, supplemented by industry investment, aims to set Ireland on a path to achieve its 5.7 TWh biomethane target by 2030[34]. To support the decarbonisation of the heat sector, the Irish Government will introduce a Renewable Heat Obligation (RHO) by the end of 2024. This legislation will require fossil fuel suppliers to include a proportion of renewable energy in their supply, reducing emissions and dependence on imported fossil fuels, and enhancing energy security. A public consultation on the RHO, conducted in 2023, received 51 submissions, and the policy will recognize biomethane as an eligible fuel, with phased implementation starting at 2% renewable energy content, increasing to 10% by 2030[34].

The current proposal for the RHO includes an initial 2% renewable energy requirement for suppliers, gradually increasing to 10% by 2030 to support the development of the indigenous biomethane sector and achieve the government's target of 5.7 TWh by 2030. The CAP 24 commits to publishing a high-level RHO scheme by Q3 2024, detailing target rates, obligated periods, and scheme duration, with careful management to align annual obligation rate increases with the availability and sustainability of renewable fuels [34].

Anaerobic digestion (AD) plants are capital-intensive, with high operational costs driving up the per-unit revenue needed and the 'green premium' over fossil gas. To mitigate this, the Irish government has secured €40 million through the Department of Agriculture for a capital grant scheme to support biomethane production. This funding, part of the REPowerEU chapter, aims to upscale the biomethane industry to 1 TWh initially, with plans to expand to 5.7 TWh by 2030. Existing and new AD plants can apply, focusing on sustainability and agri-led production[34].

Table 14. *Renewable Incentive[34]*

Measures		Period	Aim
Introduction of Renewable Heat Incentive (October 2024)	Initial Grant Support Programme (DAFM)	2024 - 2025	Contribute to 1 TWh CAP target of indigenous biomethane
	Further Grant Support Programme	2026 - 2030	Contribute at least an additional 1.5 TWh of indigenous biomethane

[34] *Government of Ireland*.2024. Ireland's National Biomethane Strategy. https://www.gov.ie/en/publication/d115e-national-biomethane-strategy/. Accessed on 07 July 2023.

5.1 Economic Impacts of Biomethane Production

There is a significant contribution from agriculture to the Irish economy, with about 8% of jobs and about 11% of exports generated by the sector. Utilizing Irish agricultural resources more effectively will boost self-sufficiency and economic growth. The Irish Bioenergy Association's (IrBEA) research into the economic impact of biogas Anaerobic Digestion (AD) plants shows their significant role in generating output, employment, and investment (table 16). The cost of establishing and running these AD facilities can vary greatly. This variation is tied to the specific technology employed in the AD plants, with more advanced technologies potentially increasing initial costs but offering better efficiency. The type and availability of feedstocks also play a crucial role in influencing the cost and efficiency of these plants[35].

Table 15.*The potential economic impact of AD-Biomethane facilities* [35]

Key Assumptions	Per Unit	Total
Small On-farm AD		
Number of Facilities		30
Feedstock Capacity (tonne)	22,000	660,000
• Grass Silage (50%)	11,000	330,000
• Slurry (50%)	11,000	330,000
Bioenergy Output (MWe)	0.25	7.50
Bioenergy Output (MWth)	0.25	7.50
Bioenergy Contribution to RES-E (ktoe)		4.8
Bioenergy Contribution to RES-H (ktoe)		4.8
Investment Costs	€ 1.25 million	€37.5 million
Annual Operation and Maintenance Costs (7%)	€0.09 million	€2.62 million
Direct Employment – O&M	1	30
Medium On-farm AD		
Number of Facilities		30
Feedstock Capacity (tonne)	45,000	1,350,000
• Grass Silage (50%)	22,500	675,000
• Slurry (50%)	22,500	675,000
Bioenergy Output (MWe)	0.5	15.0
Bioenergy Output (MWth)	0.5	15.0
Bioenergy Contribution to RES-E (ktoe)		9.7
Bioenergy Contribution to RES-H (ktoe)		9.7

[35] *IrBEA, 2012. The Economic Benefits from the Development of BioEnergy in Ireland to meet 2020 Targets*, https://www.irbea.org/irbea-report-economic-benefits-development-bioenergy-ireland-meet-2020-targets/. *Accessed 20 October 2022.*

Investment Costs	€ 2.5 million	€75 million
Annual Operation and Maintenance Costs (7%)	€175,000	€5.25 million
Direct Employment – O&M	2	60
Large On-Farm AD		
Number of Facilities		10
Feedstock Capacity (tonne)	60,000	600,000
• Grass Silage (33%)	20,000	200,000
• OFMSW/food waste (33%)	20,000	200,000
• Slurry (33%)	20,000	200,000
Bioenergy Output (MWe)	1.0	10.0
Bioenergy Output (MWth)	1.0	10.0
Bioenergy Contribution to RES-E (ktoe)		6.5
Bioenergy Contribution to RES-H (ktoe)		6.5
Investment Costs	€ 5.0 million	€50 million
Annual Operation and Maintenance Costs (7%)	€350,000	€3.5 million
Direct Employment – O&M	4	40
Large Off-farm AD		
Number of Facilities		4
Feedstock Capacity (tonne)	40,000	160,000
• ABP (50%)	20,000	80,000
• Separated MSW (50%)	20,000	80,000
Bioenergy Output (MWe)	1.0	4.0
Bioenergy Output (MWth)	1.0	4.0
Bioenergy Contribution to RES-E (ktoe)		2.6
Bioenergy Contribution to RES-H (ktoe)		2.6
Investment Costs	€ 15 million	€60 million
Annual Operation and Maintenance Costs (7%)	€1.05 million	€4.2 million
Direct Employment – O&M	6	24
Large On-Farm - Biomethane		
Number of Facilities		5
Feedstock Capacity (tonne)	50,000	250,000
• Grass Silage (58%)	29,000	145,000
• Slurry (42%)	21,000	105,000

Bioenergy Contribution to RES-H (ktoe)		9.0
Investment Costs	€ 7 million	€35 million
Annual Operation and Maintenance Costs (7%)	€ 490,000	€2,45 million
Direct Employment – O&M	4	20
Large Off-farm - Biomethane		
Number of Facilities		5
Feedstock Capacity (tonne)	50,000	250,000
• ABP (50%)	25,000	125,000
• OFMSW/Food waste (50%)	25,000	125,000
Bioenergy Contribution to RES-H (ktoe)		18.8
Investment Costs	€ 15 million	€75 million
Annual Operation and Maintenance Costs (7%)	€ 1.05 million	€5.25 million
Direct Employment – O&M	6	30

5.2 Biogas Producers in the South-East Region

In the South-East region, six AD plants are operational, but there are no biogas plants under construction (Table 17)[36]. The South-East region has significant potential to increase capacity for the production of biogas and biomethane. With the increase in fossil fuel prices in recent years, the gap between cost of production and market return has closed. The gap between farmer engagement and income diversification must be bridged through policies, incentives, and support. In recent years, income diversification has become a key selling point for AD investors.

Table 16. *Biogas producers in the South-East region*[36]

Name	County	Feedstock [t]	Biogas production m^3/yr	Energy Value MWh/yr
BEOFS, Bio Energy Organic Fertiliser Services	Kilkenny	10,000	200,000	1,333
Ballyshannon Recycling Ltd	Wexford	15,000	219,000	1,460
Malcolm Rothwell	Wexford	19,000	N/A	N/A
Ormonde Organics	Waterford	58,000	N/A	53,725
Kilgreany AD	Waterford	N/A	N/A	N/A
Ashleigh farms, Biowave	Waterford	N/A	N/A	N/A

BEOFS is a community anaerobic digestion-based project which supplies heat and power to Camphill Ballytobin Community inclusive village. The plant has been operating since 1999 and is a small scale centralised anaerobic digestion plant. The AD is fed by slurry collected from four local farms plus co-digested kitchen waste and food processing wastes. The biogas produced supplies heat and electricity to the community. The digestate is sent back to the farmers and used as fertilisers and the solid residues are composted before being used as soil conditioner.

Ballyshannon Recycling Ltd. is an anaerobic digestion facility founded in 1996 on a 198-acre dairy farm, which host the Carrigbyrne Cheese cheesemaking company. The AD plant is fed by slurry collected from the dairy farm, and waste from the cheese plant. 1,100 m^3 of biogas are produce per day, supplying power for the cheese making process, and to the national grid. Digestate from the AD process is spread on the farmland. Ormonde Organics facility will be capable of upgrading 750m^3 per hour of biogas generated at their existing AD plant into renewable gas. This will displace 5,000 tonnes of CO_2 along with further CO_2 savings by using the digestate to replace artificial fertilisers.

Planning permission application submitted in DunBell Kilkenny to supply Mitchelstown Injection Hub proposed by Gas Networks Ireland in 2021. It is proposed that the plant will process 19,800 tonnes per annum of rotation, catch crops such as whole crops, triticale barley and excess grass and 10,000 tonnes per annum of cattle slurry from on farm beef and heifer units. This quantum feedstock equates to approximately 83 tonnes per day, which will in turn generate 500 m3 of biogas with a runtime of 8,600 hours per annum. The plant will use anaerobic digestion technology and proven biogas upgrading technology to convert the input organic material into biomethane and organic fertiliser, termed digestate.

[36] Vliexs,D.2021.*Details of negotiation processes and formal structures for RE partnerships for creating regional RE supply-demand partnerships developed. RegEnergy Report. South East Energy Agency.*


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6.0 Potential CNG Stations in South East Region

The development of Compressed Natural Gas (CNG) refueling infrastructure in Ireland, including the South-East region, is progressing, with a focus on expanding the network to support the country's carbon reduction targets. Gas Networks Ireland is leading this development and has established several CNG stations across Ireland. As of now, there are eight operational CNG stations in the country, with more in the pipeline at various stages of design, planning, and construction[37]. These include both public and private stations, catering to the needs of fleet operators and hauliers who require on-site refueling stations. The map (Figure 15) highlights the CNG stations, providing a geographical context of the region and their locations in relation to major cities, roads, and landmarks. The right box in Figure 15 explains that Gas Networks Ireland and Circle K inaugurated Ireland's first public, fast-fill compressed natural gas (CNG) refuelling station in December 2018. This facility, located at Circle K's Dublin Port premises, utilizes fast-fill technology and has the capability to refuel up to 70 heavy goods vehicles (HGVs) per day, with each refuel taking no more than five minutes.

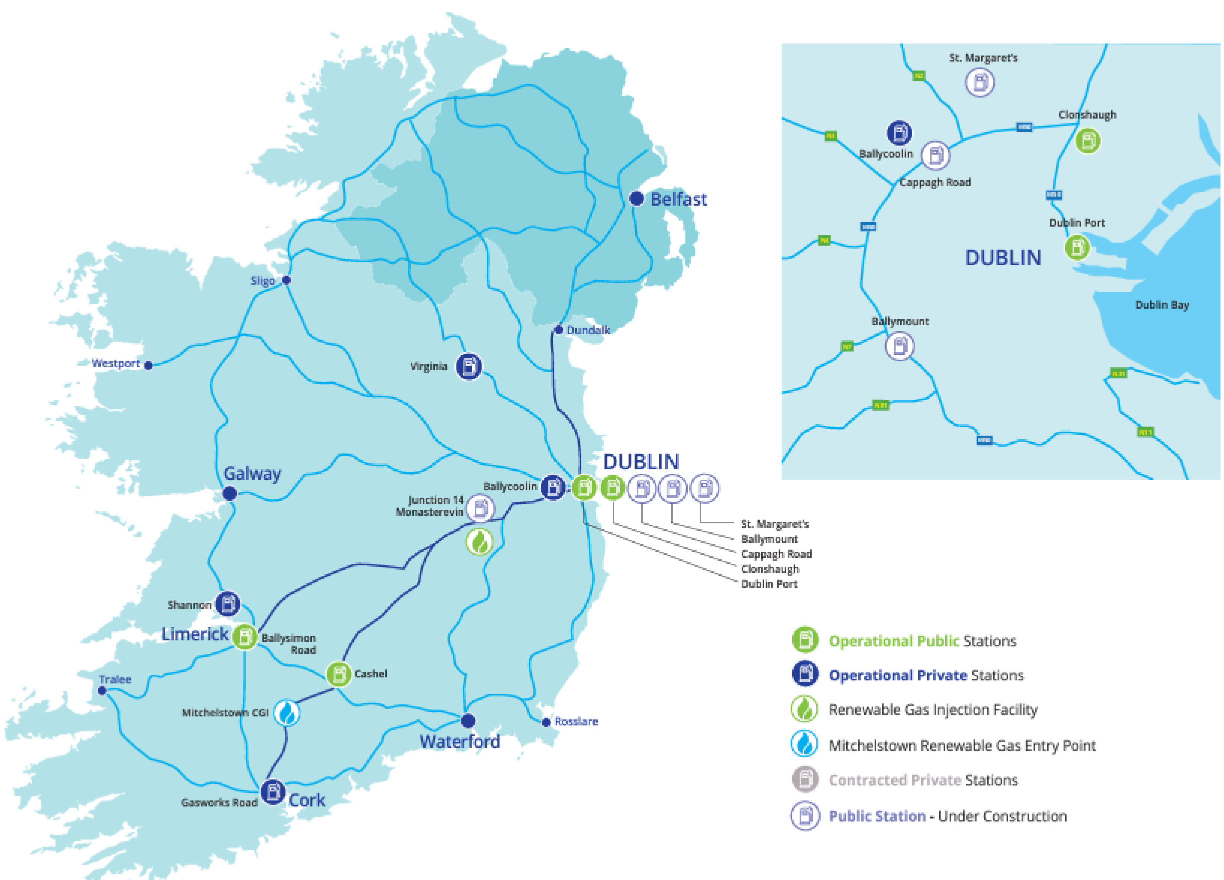

***Figure 14**. CNG refueling stations in Republic of Ireland[32]*

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[37] *Gas Network Ireland. 2021. Compressed Natural Gas refueling stations. https://www.gasnetworks.ie/business/natural-gas-in-transport/cng-refuelling-stations/. Accessed on 07 July 2024.*

Further expansion occurred in 2021, with the opening of two additional public CNG stations at Ballysimon Road, County Limerick, and Clonshaugh, County Dublin. These strategically located stations opened new transport corridors for existing CNG customers and facilitated further reductions in the environmental impact of their fleets.

The development of the CNG refueling network is part of Ireland's larger strategy to decarbonise its transport sector, particularly heavy goods vehicles, which are a significant contributor to road transport emissions. The use of CNG, and eventually renewable gas, in transport is seen as a key solution in this regard. Gas Networks Ireland's investment in this infrastructure is supported by various grants and is in line with the country's commitment to a cleaner, more sustainable future.

The CNG fueling facility requires an optimal location to accommodate the complex requirements of a CNG fueling system and traffic flow. Through a series of meetings with GNI, several sites were identified as possible locations for the CNG fueling facility. To accommodate an operation of this magnitude several criteria were developed that identify the preferred option among the list of possible CNG fueling sites for HGVs and Bus fleets in the South-East region.

6.1 Heavy Goods Vehicles

The potential development of Compressed Natural Gas (CNG) stations for Heavy Goods Vehicles (HGVs) in the South-East region of Ireland represents a strategic advancement in green logistics and transportation. By situating these stations in this region, HGV operators would gain access to a more environmentally friendly alternative to diesel, which is typically used in long-haul transportation. In this phase of the feasibility study, the analysis is based on the following general basic tenets:

- It should be ideal for the preferred site be located nearest to the natural gas pipelines. The greater the distance between the supply and the fuelling station the more the cost.
- Based on the traffic flow of the HGV's the ideal location should be close to the motorways and highways.

The use of Geographic Information Systems (GIS) has been instrumental in identifying potential sites for Compressed Natural Gas (CNG) refuelling stations for Heavy Goods Vehicles (HGVs) in the South-East region of Ireland (Figure 16). The precise siting criteria for these stations took into account their proximity to existing gas grid infrastructure, as well as ease of access from major motorways and highways, ensuring that they are no more than 2 kilometres away from the gas grid. This strategic placement is designed to facilitate seamless integration into the existing transportation networks and to provide convenient refuelling points for HGVs operating in the area. This network will facilitate a shift towards cleaner transportation options, aligning with national goals for reducing carbon emissions and promoting alternative fuels. Figure 16 below, highlights the potential CNG stations for HGV's.
The strategic placement of these stations is planned as follows:

- **County Carlow**: 2 proposed CNG stations to support the county's logistic routes and agricultural industry.
- **County Kilkenny**: 3 proposed stations, which will cater to the region's mixed agricultural and industrial activities and also provide support for HGVs that navigate through this historical and commercial area.
- **County Waterford**: With 8 potential stations, this county is set to have a significant concentration of refueling options, reflecting its active port operations and its role as a transport hub in the region.
- **County Wexford**: 1 station to enhance the connectivity and refueling options for HGVs, especially those involved in trade through the Rosslare Europort.

This infrastructure development is poised to make a significant contribution to the environmental and economic landscape of the South-East region, by providing a sustainable and cost-effective alternative to diesel for the transport sector.

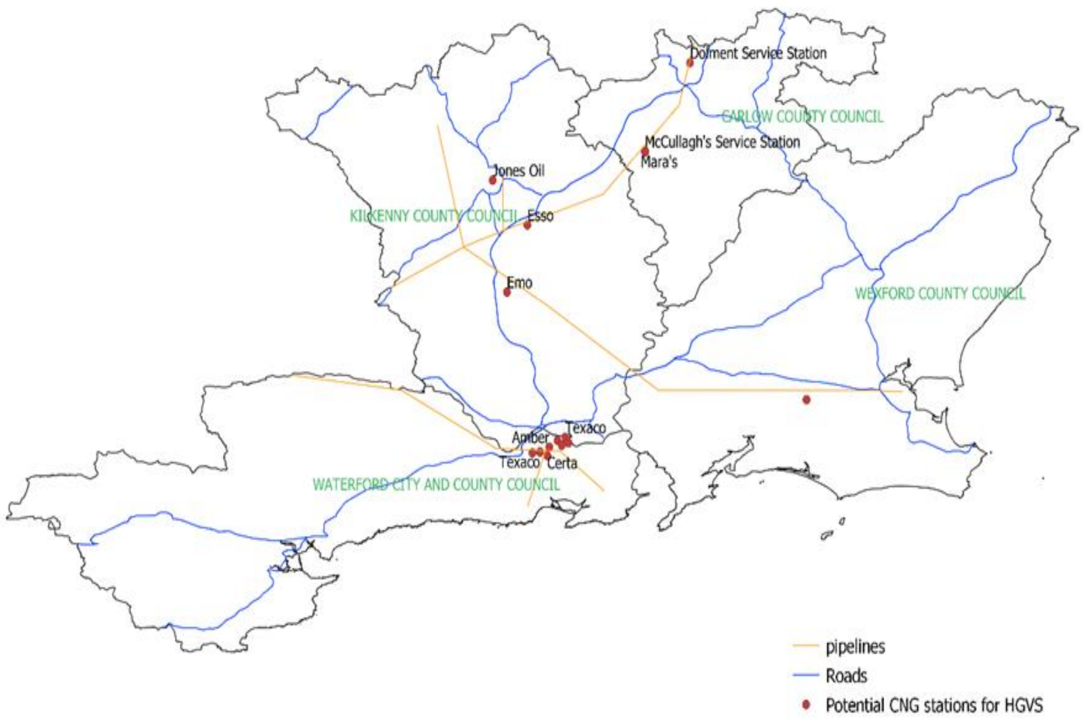

Figure 15. *Potential CNG fuelling stations for HGV's*

6.2 Buses

The strategic development of Compressed Natural Gas (CNG) stations in the South-East region of Ireland is particularly advantageous for the bus transportation sector. Buses, as frequent and consistent road users, stand to gain significantly from the shift to a cleaner and more cost-effective fuel alternative like CNG, which offers a lower-carbon option compared to traditional diesel. The potential deployment of CNG refuelling stations in this region aligns with Ireland's broader environmental objectives and its commitment to reducing greenhouse gas emissions. By providing accessible refuelling infrastructure, the transition to CNG buses is facilitated, enabling public transport and private coach services to operate more sustainably.

The introduction of CNG stations could catalyse a shift not only for public transportation but also for private sector fleets, including school buses and tour coaches. This transition supports the local economy by lowering operational costs for bus operators, given that CNG typically offers a more stable price compared to diesel. Moreover, passengers benefit from cleaner air due to lower emissions of particulates and NOx gases.

The location of these potential stations would be pivotal. Ideally, they would be sited at key points where bus routes converge, such as near bus depots, major traffic interchanges, or hubs of public activity like town centres and tourism spots. Proximity to bus depots would streamline operations by reducing refuelling time and logistics, while stations near heavy traffic areas would ensure that buses on longer routes can refuel as needed without significant detours. The following criteria were used for the evaluation of the prospective sites:

- It should be ideal for the preferred site be located nearest to the natural gas pipelines. The greater the distance between the supply and the fuelling station the more the cost.
- The preferred site should have private CNG stations for the fleet operators who want their own on-site refuelling depots.

The integration of Geographic Information Systems (GIS) has facilitated the identification of potential sites for Compressed Natural Gas (CNG) stations, specifically tailored to accommodate buses in the South-East region of Ireland (Figure 17). The proposed CNG stations are conveniently located within a 3-kilometer radius of the existing gas grid, and strategically placed at or near bus depots. This ensures that the refuelling infrastructure is both accessible and efficient for bus fleets, minimizing any disruption to service or route deviations.

The planned network includes two potential CNG stations in County Waterford, where the blend of urban and rural transit operations presents a prime opportunity for reducing the carbon footprint of public and private bus fleets. Additionally, a single CNG station is anticipated for each County Kilkenny, County Carlow, and County Wexford. These stations would provide essential coverage across the region, ensuring that even buses on the longest routes have ready access to CNG.

The placement of these stations at bus depots underscores a commitment to operational efficiency. By locating refuelling points at central nodes within the bus transportation network, the stations can serve a dual purpose: facilitating quick and easy refuelling for buses as they complete their daily routes, and serving as hubs for maintenance and overnight parking. Figure 17 below, highlights the potential CNG stations for Buses.

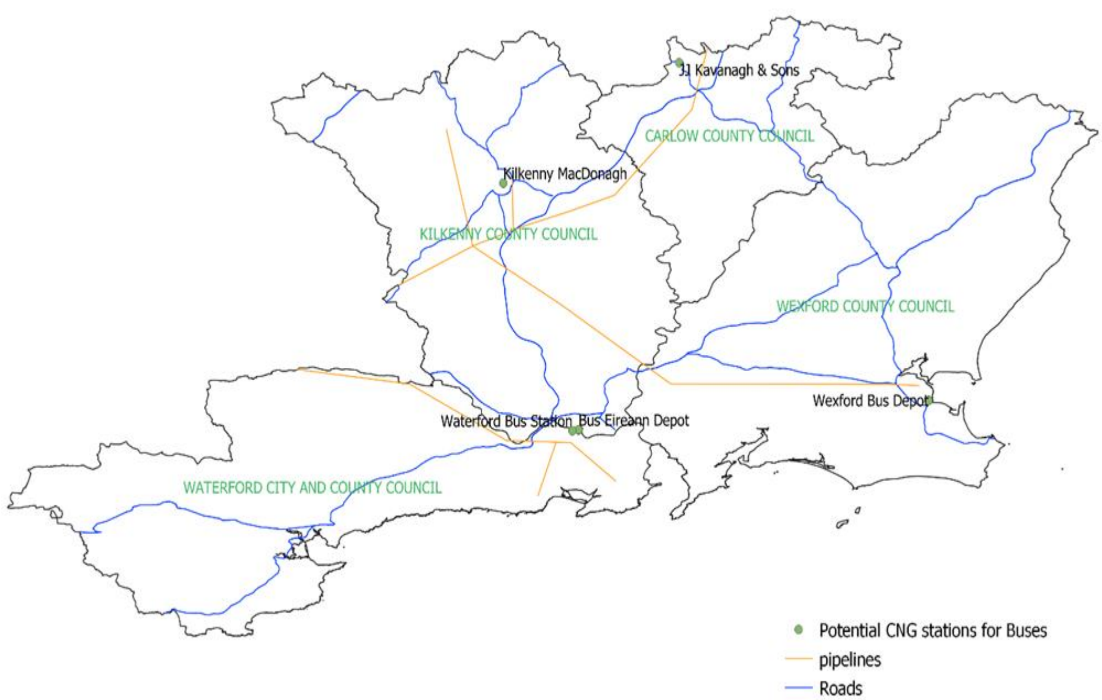

Figure 16.*Potential CNG stations for Buses*

7.0 Conclusion

The assessment of the potential for renewable gas and the development of Bio-CNG in Ireland's South-East region paints a promising picture for sustainable energy production. The region boasts a significant capacity for biogas production, currently estimated at 987 Gigawatt-hours (GWh) and potentially rising to 6,671 GWh with optimal resource management. Grass silage stands out as a key contributor, with its current and future potential for biogas and hydrogen production. The conversion of biogas from grass silage, animal slurry, WWTPs, and landfills into biomethane and hydrogen presents a valuable opportunity, especially considering the growing demand for renewable energy sources.

Despite facing challenges such as logistical complexities, high production costs, and regulatory barriers, the biomethane market in the South-East is supported by a favorable policy environment and increasing interest in renewable alternatives for heating, electricity, and transportation fuel. This interest is further enhanced by the economic incentives arising from the recent rise in fossil fuel prices. The existence of six operational anaerobic digestion (AD) plants in the region, coupled with identified potential locations for CNG filling stations and the use of hydrogen in Fuel Cell Electric Vehicles (FCEVs), underscores the substantial scope for expanding biogas and biomethane production capacity. This expansion is not only economically viable but also crucial for environmental sustainability, as the transportation sector is a major contributor to greenhouse gas emissions.

The South-East region of Ireland holds significant potential for renewable gas production and Bio-CNG development. With continued support through targeted policies and incentives, and by addressing existing challenges, this region can become a leading example of how renewable energy can contribute to environmental goals and economic development. The transition to renewable gas, especially in the transportation sector, offers a path towards reducing greenhouse gas emissions and achieving energy sustainability.

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