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Gas Networks Ireland

Biomethane Producers Technical Handbook

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Biomethane

Fundamentally identical to natural gas, biomethane is a carbon neutral renewable gas that can be made from farm and food waste through a process known as anaerobic digestion (AD).

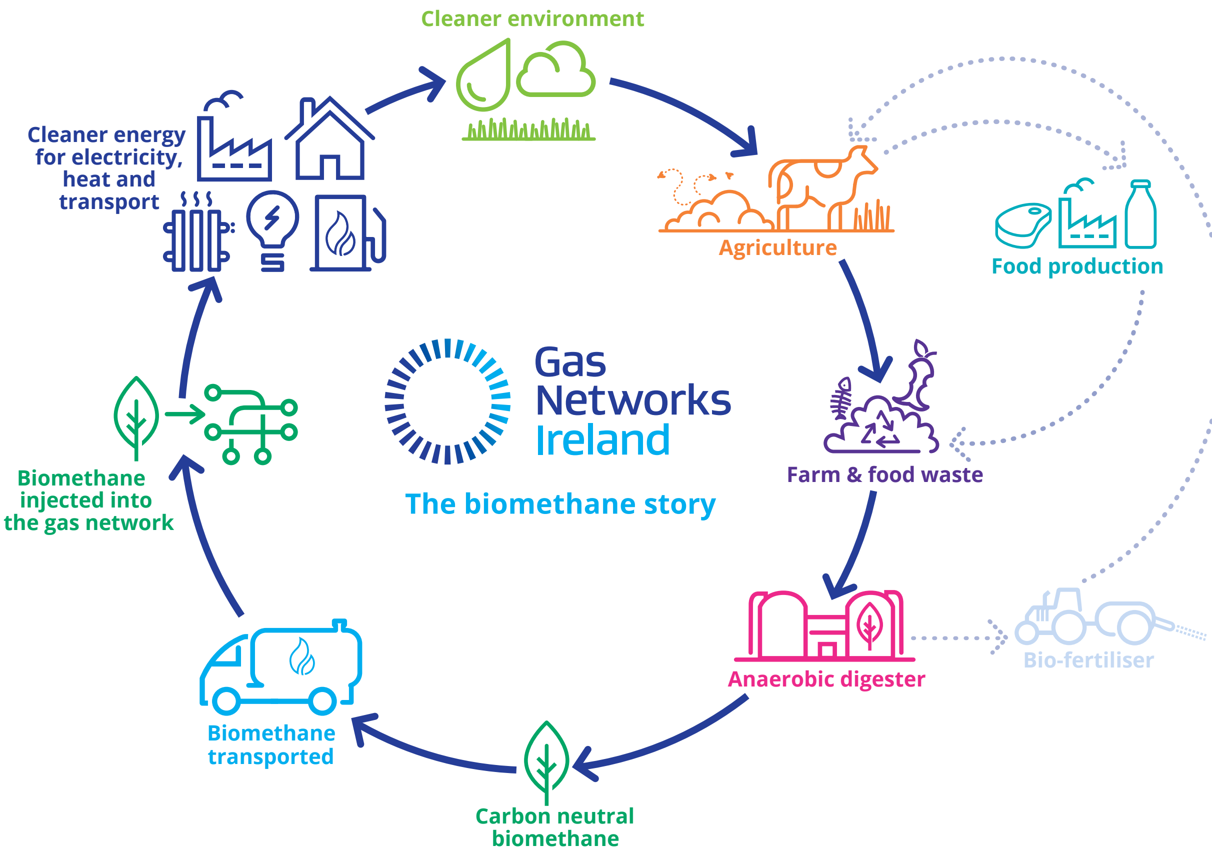
It is fully compatible with the national gas network and existing appliances, technologies and vehicles, and can seamlessly replace natural gas to reduce emissions in heating, industry, transport and power generation, while also supporting the decarbonisation of the agri-food sector.

Ireland began its journey to a net-zero carbon gas network in 2019, with the introduction of domestically produced biomethane in County Kildare, through Ireland's first purpose built injection facility in Cush. Development is now underway for a second renewable gas injection point near Mitchelstown in County Cork that will have the potential to heat up to 64,000 homes.

Replacing natural gas with renewable gases such as biomethane, an essential bridging step in Ireland's decarbonisation, can play an important role in meeting the 2030 emissions reduction target, achieving net zero emissions by 2050 and sustainably deliver a net zero carbon gas network.

Ireland's national gas network provides almost one-third of all primary energy, 40% of heating, and nearly half of Ireland's electricity generation. It is among the safest and most modern gas networks in the European Union and can help significantly decrease emissions by facilitating a more sustainable and secure transition to a clean energy future.

Replacing natural gas with a carbon neutral renewable gas such as biomethane, can therefore play a vital role in helping Ireland meet its 2030 emissions reduction target, achieve net zero emissions by 2050 and sustainably deliver a net zero carbon gas network.



The European Commission's REPowerEU plan recognised the potential of renewable gases by announcing the European Union's (EU) ambition to increase the production and use of biomethane throughout Europe.

Ireland's 2021 Climate Action Plan set an initial target of 1.6TWh/yr of biomethane on the national gas network by 2030 and outlined the Government's intent to explore opportunities to increase production and further reduce emissions in the agri-food sector.

This biomethane production target was later updated, as the Government outlined its decision on Sectoral Emissions Ceilings in the Budget 2023 publication 'The Use of Carbon Tax Funds 2023'. This set out an increased ambition for domestic biomethane production of up to 5.7 TWh, which equates to approximately 10% of Ireland's current required gas supply.

Now at the cusp of Ireland's promising biomethane industry, the need to scale up production to meet this increased ambition is immediate. In addition to decarbonising Ireland's gas network, indigenously produced biomethane could also enhance Ireland's energy security by reducing its dependency on imported fossil fuels.

As the operator of Ireland's gas network, Gas Networks Ireland is playing a key role in delivering Ireland's biomethane ambition, by sustainably and safely transporting biomethane on the network.

To prepare for increased biomethane connections and injection, Gas Networks Ireland is developing a coordinated gas network plan. This will outline the development of the gas network to bring biomethane to almost 720,000 homes and businesses across the country in the most efficient and cost-effective manner.

Anaerobic digestion

AD produces biogas through the microbial degradation of organic compounds in the absence of oxygen, where the bulk of organic matter, generates digestate rich in nutrients.

AD is recognised as a potential solution to address the global challenge of waste and residue management as well as addressing energy and climate challenges and provide an alternative to chemical fertilisers. There are several countries with thousands of AD plants producing biomethane, which is transported through the gas network to both domestic and commercial customers.

AD is a proven technology, and is considered a simple process when compared with other biological and thermal technologies for the processing of organic wastes. Coupled with its adaptability to a wide spectrum of feedstocks, this has led to its current growing scale of adoption worldwide.

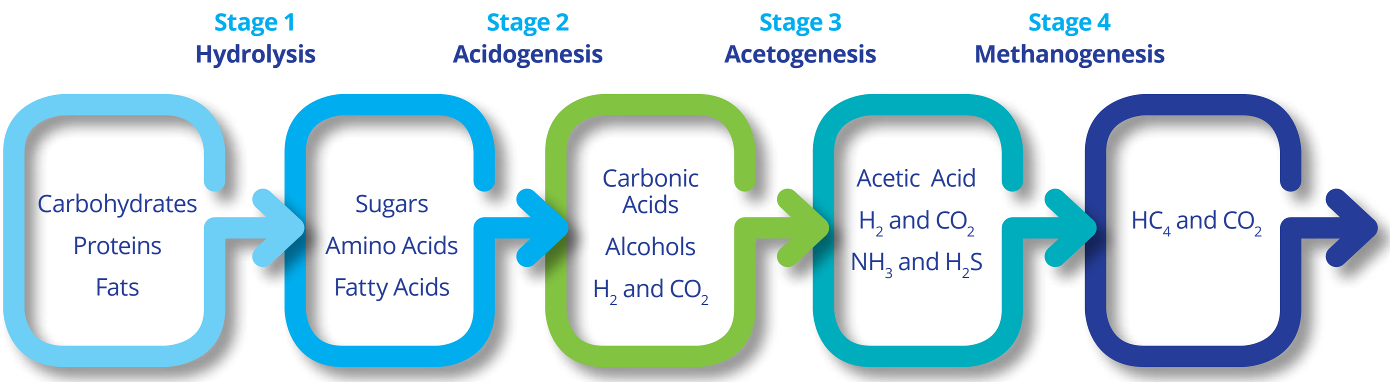
As the technology has evolved, AD facilities can now be best described as **AD biorefineries where**;

- More advanced pre-treatments can extract higher value constituents (such as proteins), enhancing the effectiveness of feedstocks and reducing greenhouse gas (GHG) emissions.
- Raw biogas is cleaned and separated into **biomethane** and biogenic CO_2.
- Raw digestate (the biofertiliser produced as a by-product of AD) is further processed into organic fertiliser (nitrogen, phosphorous and potassium), soil improvers in forms that are optimal to the land requirements.
- Renewable energy (solar photovoltaic panels, green hydrogen, and biomethane) provides more of the energy and fuel needed to meet the lifecycle energy demand of the facility.
- A modern AD biorefinery will typically have a net negative lifecycle GHG emissions.

Anaerobic digestion biochemistry

The quality of the outputs of the AD process – the raw biogas and digestate are highly dependent on the balance of the four stages in the process. These stages are hydrolysis, acidogenesis, acetogenesis and methanogenesis.

The biochemical reactions that take place during these four stages are governed by the microbial community in the AD reactor, with the products and co-products formed at each stage influencing prior and subsequent stages. This means that a balanced microbial consortium of hydrolysing bacteria, acidogenic bacteria, acetogens and methanogens are required in the system. Similarly, the composition of the feedstock, or mixture of feedstocks, in the AD system, will impact upon the progression and efficiencies of each of the four stages.



Stage 1 Hydrolysis
Complex carbohydrates, proteins, and fats are hydrolysed to sugars, amino acids, and fatty acids, respectively.

Stage 2 Acidogenesis
These monomers are converted to volatile fatty acids (VFAs), alcohols, and gases in the second stage.
The concentration of VFAs has a significant effect on methanogenesis and is one of the key process indicators.

Stage 3 Acetogenesis
Acids and alcohols are converted to acetic acid, hydrogen, carbon dioxide and other gases.

Stage 4 Methanognesis
Hydrogenotrophic methanogens utilise hydrogen and carbon dioxide or formate to produce methane whilst acetoclastic methanogens produce methane from acetate produced in the second and third stages.

In well-managed AD systems, all four stages are perfectly synchronised, for example with VFAs concentrations kept under control by active methanogenic bacteria.

Anaerobic digestion feedstocks

AD can be used to produce biogas and energy from a variety of organic feedstocks, while addressing the challenges of waste and residue management.

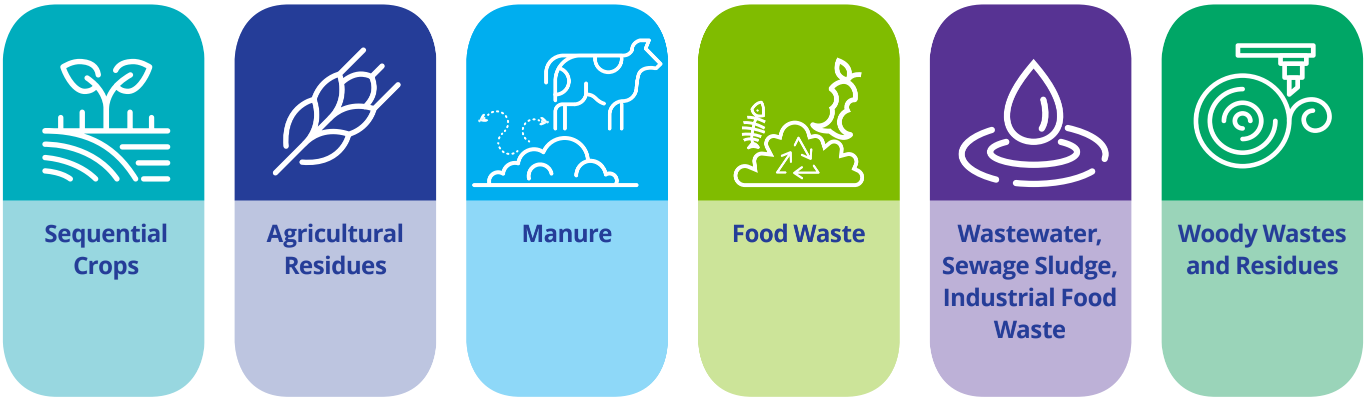
The type of feedstock used is key as it will influence not only the AD process itself, but also the quality of the outputs - biogas and digestate.

AD facilities that rely on a small subset of agricultural residues and energy crops and on-site AD facilities that deal with the outputs of a particular industrial process tend to have relatively consistent supplies of reasonably homogeneous feedstocks.

Stand-alone AD plants that use feedstocks from a variety of sources tend to have inconsistent levels of supply and heterogeneous feedstock compositions that can cover wide ranges of levels of complex carbohydrates, proteins, lipids, sugars, and acids.

The EU Renewable Energy Directive (January 2021) stipulates the mandatory obligations that all AD biomethane and AD biorefinery facilities are required to pass a full lifecycle emissions assessment (LCA) for each annual cycle of operation. It also stipulates that the plants be independently verified and certified in line with this standard. For agriculture feedstock-based facilities, this mandatory standard will typically require the facilities to be designed and operated to utilise a minimum of 40% animal slurries or equivalent (within each annual assessment cycle).

Sustainable biomass feedstocks for biomethane production such as:



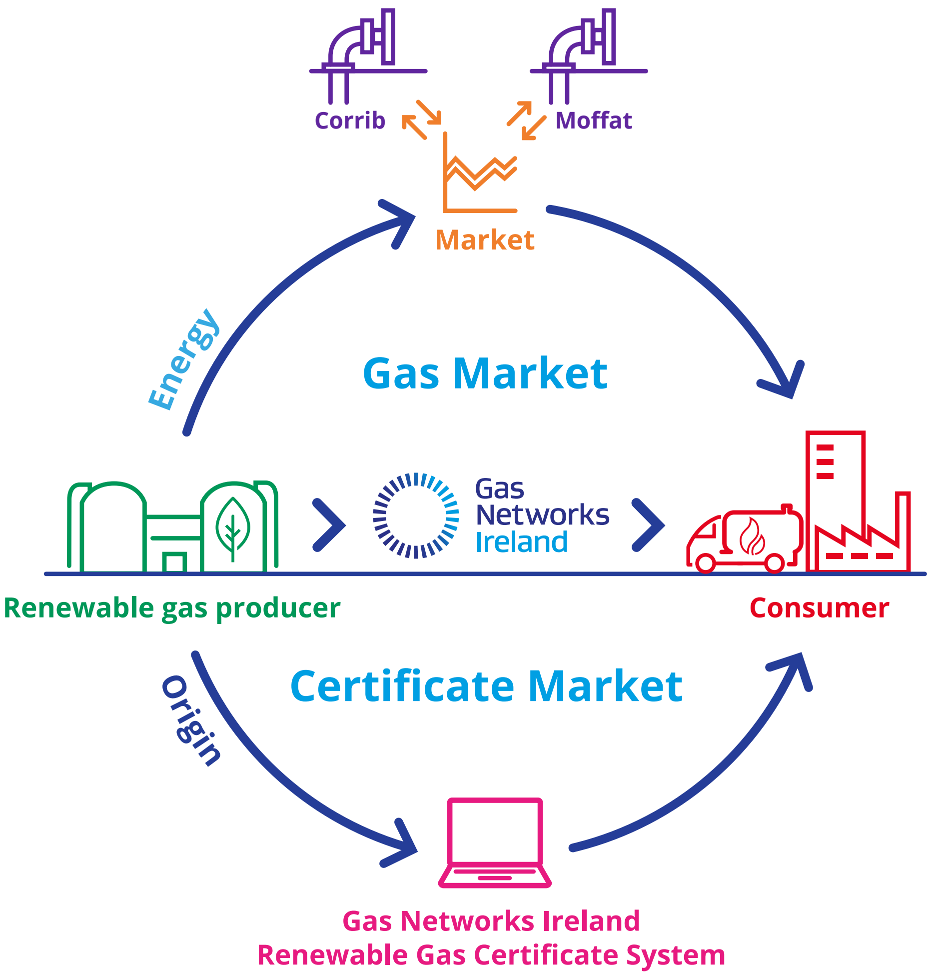
Renewable gas certification

Gas Networks Ireland was appointed as the body responsible for issuing Guarantees of Origin Certificates for renewable gases in line with European Union Renewable Energy Directive (RED) 2021, which passed into Irish law in early 2022.

Each certificate guarantees that the biomethane is produced and independently verified to this RED standard and that the equivalent amount of biomethane has been injected into the gas network. The register facility operated by Gas Networks Ireland then provides a means of tracking commercial transactions of biomethane through the supply chain.

For more information on certification and **guarantees of origin for renewable gases,** contact **RGcertificates@gasnetworks.ie**

or visit **www.gasnetworks.ie/renewable-gas-registry**



Biomethane potential

Biomethane potential (BMP) is defined as the maximum theoretical methane potential possible from a given feedstock attained under conditions where all the organic material is converted to biogas, with no residual digestate produced. However, as some of the feedstock will be converted into microbial matter and it is unlikely that all of the organic matter (e.g. the lignin) will be fully converted, the actual biomethane outputs of AD will be less than the BMP.

It is generally recommended that biomethane producers undertake BMP testing with a representative sample of each feedstock being considered for use.

In Ireland, this service can be obtained via Limerick based Celignis Analytical (www.celignis.com) over retention periods of 14, 21, 28 or 40 days. BMP analysis also determine the total solids (TS) and volatile solids (VS) contents of the sample and also involve periodic analyses of the composition of the biogas (for methane, carbon dioxide, hydrogen sulphide, oxygen, and ammonia).

Optimal anaerobic digestion

In order to achieve maximum biogas yields from the AD process, key chemical and physical parameters should be monitored.

These can be divided into process parameters and process indicators.

Process parameters include; quantity and composition of feedstock; total solids (TS); volatile solids (VS); BMP; NH4-N; organic loading rate (OLR); temperature; pH; mixing; and hydraulic retention time. Key process indicators are; total biogas yield; biogas composition; volatile fatty acids (VFAs); Alkalinity ratio (FOS/TAC); and redox potential.

Perameter	Target ranges for stable process
pH	7 – 8
NH_4-N	<3000 mg/L
Total VFAs	<1000 mg/L
Alkalinity ratio	<0.3
Redox potential	< -300 mV

Process parameters and indicators should be routinely checked, ideally, temperature, pH, biogas composition, and mixing should be checked twice a day; with TS, VS, and organic loading rate monitored once a day.

Any changes of feedstock type, organic loading rate and hydraulic retention time (HRT)[1] and solid retention time (SRT)[2], should be undertaken gradually in order to allow microbes to adapt to the new conditions.

When a different type of feedstock is introduced, any changes taking place in the biogas composition, pH or VFAs concentration should be closely and frequently monitored to predict and pre-empt failures in the AD process.

The VFAs and alkalinity ratio for a stable digester should be tested twice a month. However, more frequent testing is warranted in cases where digester fluctuation results from changes in feedstock type and supply.

[1] Hydraulic retention time (HRT) is a measure of the average length of time the liquid/soluble compound remains in AD reactor.

[2] Solid retention time (SRT) is a measure of the average length of time solid compounds remain in AD reactor.

Measuring efficiency

The efficiency of the AD process can be tested by performing simple mass balances based on the composition of the feedstock and its volatile solids content coupled with the same set of analyses on the digestate.

An efficient biogas plant will maximise the digestion of organic matter and its conversion to methane, resulting in minimal amounts of organic material in the digestate.

However, in many cases AD facilities do not fully digest the feedstock, typically because of high organic loading rates and low hydraulic retention times. It is often necessary that the digestate is tested for its residual biogas potential (RBP) to determine how efficiently the feedstock has been digested. The RBP is a lab-based test, based on the BMP test, that takes digestate as the starting material and determines how much biogas can be produced from its digestion in controlled conditions. Any biogas and biomethane produced in the RBP tests can be lost potential yields from the previous digestion of the sample in the AD system.

AD efficiencies can also be reduced when organic matter is converted to carbon dioxide rather than methane. This phenomenon can be avoided by increasing the concentration of methanogens in the AD reactor either by augmenting with a high methane producing inoculum source or by providing feedstock and process conditions that can enrich methanogens concentrations.

Improving efficiency

One way to improve AD process efficiency is to alter the co-digestion with nutrient and pH complimenting feedstocks.

However, the fine-tuning of the co-feed ratio of different feedstocks for co-digestion, organic loading rate, and hydraulic retention time optimisation will be dependent on the feedstocks being considered. The optimum ratio varies substantially according to which co-feed feedstock is used.

Other ways to improve process efficiencies and yields include:

- Using chemical agents to balance nutrients and pH
- Allowing for an adaptation of the microbial inoculum to the unfavourable process conditions (e.g. via a long start-up phase)
- Supplementing enzymes to increase reaction rates.

Biomethane specification

Cleaned, separated and purified biogas is called biomethane and is required to meet a technical specification to permit its use as a fuel and for injection into the gas network.

The specification requirements for biomethane in Ireland are summarised in the following tables.

There are several technologies and technology providers on the market, however, Gas Networks Ireland recommend technical solutions that can consistently achieve biomethane levels of 99% and above.

Parameter	Units	Limit Value	Notes
Hydrogen sulphide (H2S) content	mg/m³	≤5	As per Gas Networks Ireland Code of Operations
Total sulphur content (including H2S)	mg/m³	≤50	As per Gas Networks Ireland Code of Operations
Hydrogen (H2) content	%mol/mol	<0.1	As per Gas Networks Ireland Code of Operations
Oxygen (O2) content	%mol/mol	≤1.0	See Note 4: Code of Operations modification to increase limit to 1 for Dx connection and <1 for Tx connections (location dependent)
Hydrocarbon dewpoint	0C	≤-2	As per Gas Networks Ireland Code of Operations (up to 85 BARG)
Water (Moisture) content	mg/m³	≤50	As per Gas Networks Ireland Code of Operations
Wobbe index (High limit)	MJ/m³	51.41	As per Gas Networks Ireland Code of Operations
Wobbe index (Low limit)	**MJ/m³**	**47.2**	As per Gas Networks Ireland Code of Operations
Incomplete combustion factor	-	<0.48	As per Gas Networks Ireland Code of Operations
Sooting index	-	<0.6	As per Gas Networks Ireland Code of Operations
Gross calorific value (CV High limit)	MJ/m³	42.3	As per Gas Networks Ireland Code of Operations
Gross calorific value (CV Low limit)	**MJ/m³**	**36.9**	As per Gas Networks Ireland Code of Operations
Carbon dioxide (CO_2) content	%mol/mol	<2.5	As per Gas Networks Ireland Code of Operations. See Note 1 of CER/09/035. Gas Networks Ireland recommend technical solutions that can consistently achieve biomethane levels of 99% and above. Where operational issues cause higher inert gas levels, limits may be temporarily accommodated, however costs and levels of boosting gas will limit this.
Organo-halides	mg/m³	<1.5	As per Gas Networks Ireland Code of Operations
Radioactivity	Becquerels/g	<5	As per Gas Networks Ireland Code of Operations
Ethane	%mol/mol	<12	As per Gas Networks Ireland Code of Operations
Nitrogen	**%mol/mol**	**≤5**	As per Gas Networks Ireland Code of Operations
Contaminants and Odour	-	-	As per Gas Networks Ireland Code of Operations. See Note 2 and 3 of CER/09/035

Continued overleaf

Parameter	Units	Limit Value	Notes
Siloxanes (Si) content	mg/m^3	0.3	This is the lower limit value of a range of values cited in EN 16723-1
Ammonia (NH3)	mg/m^3	10	This is the value cited in EN 16723-1
Amines	mg/m^3	10	This is the value cited in EN 16723-1. Compliance is dependent on the type of amine present.
Carbom monoxide (CO)	%mol/mol	0.1	This is the value cited in EN 16723-1, which in turn is that required to ensure that conveyed gas does not exceed the limit value in the CLP Regulation (EC) 1272/2008

The following table summarises the applicable European or International Standards and constituent limits for biomethane for application in grid injection or off grid where it can be used as an alternative fuel (under EU CNG and Bio-CNG Alternative Fuel standards).

Primary Standard		Impurity	Typical	Max	Ref.	Units
EN 16723_Part 01	**Gas to grid**					
ISO 16017-1: 2000		Silicon	0.3	1	TDS-GC-MS	$mgSi/m^3$
ISO 8573-2:2007		Oil				
ISO 8573-4:2001		Dust				
ISO 6974		CO		0.1		% Mol
VDI 3496		NH_3		10		mg/m^3
		CO_2				
		O_2		1		% Mol
VDI 2467		Amine		10		mg/m^3
EN 16723_Part 02	**Alternative fuel**					
	Silicon	0.1	0.5	SP	$mgSi/m^3$	
ISO 8573-2:2007		Oil				
ISO 8573-4:2001		Dust				
ISO 6974		CO		0.1		% Mol
VDI 3496		NH_3		10		mg/m^3
VDI 2467		Amine		10		mg/m^3
EN 16726		MN	65	80		
ISO 6974, 6975		H_2		2		
ISO 23874, 11150, 12148		HC Dew Point				
ISO 6974, 6975		O_2				
ISO 6326, 19739		H2S *		5		mg/m^3
		Total S				mg/m^3

Biomethane standards and safety

Gas Networks Ireland draws attention to the following key standards and safety regulations that are applicable to the production, storage and transport of biomethane. This is not intended to be a comprehensive list of the industrial and safety standards, but to act only as an introduction.

This table summarises the range of gases that can be present in the AD and AD biorefinery processes and need to be understood and managed, with particular attention to their toxicity and flammability risks.

Gas Name	Symbol	MW	BP	Toxic	LFL	UFL	UN No
Hydrogen	H_2	2			4.0%	77.0%	1049
Methane	CH_4	16	-161C		4.4%	15.0%	1971
Ammonia	NH_3	17	-33C	25 ppm TWA	15.4%	33.6%	1005
Nitrogen	N_2	28	-195C				1066
Carbon Monoxide	CO	28		30 ppm TWA	10.9%	74.2%	1016
Oxygen	O_2	32		< 15.0%			1072
Hydrogen Sulphide	H_2S	34		5 ppm TWA	3.9%	45.5%	1053
Carbon Dioxide	CO_2	44	-78C	4.0%			1033

MW = Molecular weight, BP = Boiling point, LFL = Lower flammable limit, UFL = Upper flammable limit

Essential safety and quality monitoring will be required throughout the facility, and this includes:

- Programmable Logic Controls
  - Remote Monitoring
  - Local Shut Down
  - Emergency Systems
  - Explosion Prevention Plan
- Gas Detectors – PPE
- Gas Analysis – Safety Monitoring and Access Control
- Gas Analysis – at Biomethane Network Entry Facility and Dispensing Facility
- ADR Compliance (for the storage and carriage of biomethane)

Multi-Channel Gas Alarm PPE

For facilities that intend to compress (or liquify) biomethane and other gases for road transport to grid injection, filling stations, or customer sites, then it is important to ensure compliance with the associated regulations.

Provisions relating to transport equipment used for the carriage by road of "Biomethane" (UN 1971, METHANE, COMPRESSED) in accordance with the ADR and our national regulations are summarised on the Health and Safety Authority website at **www.hsa.ie**.

The carriage of UN 1971 is subject to the provisions of the Transportable Pressure Equipment Directive 2010/35/EU (TPED).

Steel Tube Trailer

Carbon Fibre Tube Trailers

Carbon Fibre Tube Trailers

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