Alternative Uses of Biogas Group Report

A Northern Ireland Case Study

Appendix 3.2, Biogas Action Plan for Northern Ireland

Alternative Uses of Biogas Group Report

This report was prepared as a support for the Biogas Research Action Plan for Northern Ireland.

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Biogas and biomethane: upgrading standards

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Constituents of biogas and natural gas

Biogas is produced through the anaerobic digestion process, which involves the degradation of organic material in the absence of oxygen. Biogas typically consists of 45-65% methane (CH_4), 35-55% carbon dioxide (CO_2) and some minor constituents, such as hydrogen sulphide (H_2S), water vapour, organic silicon compounds (e.g. siloxanes), ammonia (NH_3), dust, and small amounts of hydrogen (H_2), air (i.e. oxygen (O_2) and nitrogen (N_2)), biological agents, and halocarbons. Indicative constituents of biogas and natural gas are presented in Table 1; it should be noted that the exact composition of biogas depends on the feedstock and the production process.

Cleaning and upgrading to biomethane standard

Biogas that has been cleaned and upgraded to the same standard as natural gas is termed biomethane. Biomethane typically consist of around 97% CH_4 and is mixable and interchangeable with natural gas. The cleaning process removes contaminants, such as H_2S, from the biogas and the upgrading process removes CO_2.

The level of cleaning and upgrading required depends on the end use of the gas (Figure 1). There is a wide range of cleaning and upgrading technologies available, information on which can be found in the literature, for example, in Persson et al (2006), de Hullu et al (2008), Petersson & Wellinger (2009), and Beil & Hoffstede (2010).

As well as cleaning and upgrading, other treatments can include:

- Odorisation. This is carried out for safety reasons to enable detection in the event of a leak. Typical compounds used are tetrahydrotiophen (THT) and mercaptans.
- Compression. The level of compression depends on the use of the gas, e.g. fast-fill/slow-fill vehicle fuel, or addition to distribution/transmission grid.
- Addition of propane or liquefied petroleum gas (LPG). These are sometimes added to increase the energy value and bring net calorific value and Wobbe index in line with quality specifications.

Table 1: Indicative composition of different raw gases from non-conventional sources and of natural gas (Marcogaz, 2006)

Composition	Units	Natural gas (typical North Sea H)	Biogas		Coal-associated gas		Biomass gasification	
			Anaerobic digester	Landfill	CMM	CBM	O_2-fired	Air-fired
Methane	mol%	88.8 (86.6 - 88.8)	65.0 (50 - 80)	45.0 (30 - 60)	65.0	90.0	15.6 (0 - 18)	2.0 (1 - 10)
C2+ Hydrocarbons		8.3 (8.3 - 8.5)	-	-	1.5	2.2	5.8 (0 - 5.8)	(0 - 2)
Hydrogen		-	(0 - 2)	1.5 (0 - 2)	-	-	22.0 (4 - 46)	20.0 (10 - 25)
Carbon monoxide		-	-	-	-	-	44.4 (13 - 70)	20.0 (9 - 25)
Carbon dioxide		2.3 (1.9 - 2.3)	35.0 (15 - 50)	40.0 (15 - 40)	16.0	3.3	12.2 (2 - 35)	7.0 (7 - 16)
Nitrogen		1.1 (0.9 - 1.1)	0.2 (0 - 5)	15.0 (0 - 50)	18.0	4.5	0 (0 - 7)	approx. 50.0
Oxygen		< 0.01	(0 - 1)	1.0 (0 - 10)	0.5	-	-	-
Hydrogen sulphide	mg/m^3	1.5 (0 - 5)	< 600 (100 - 10000)	< 100 (0 - 1000)	(0 - 5)	(0 - 5)		
Ammonia		-	100 (0 - 100)	5 (0 - 5)	-	-	-	-
Total chlorine		-	(0 - 100)	(0 - 800)				
Total fluorine	mg/m^3	-	0.5 (0 - 100)	10 (0 - 800)	-	-	-	-
Siloxanes	mg/m^3	-	0 - 50	0 - 50	-	-	-	-
Tar	g/m^3	-	-	-	-	-	0 -5	0,01 -100

NOTE: 1: all compositions are purely indicative, derived from different sources. Bracket values indicate ranges which may be encountered.

NOTE 2: For biomass gasification, different methods are available with significant differences in the composition of the product gases.

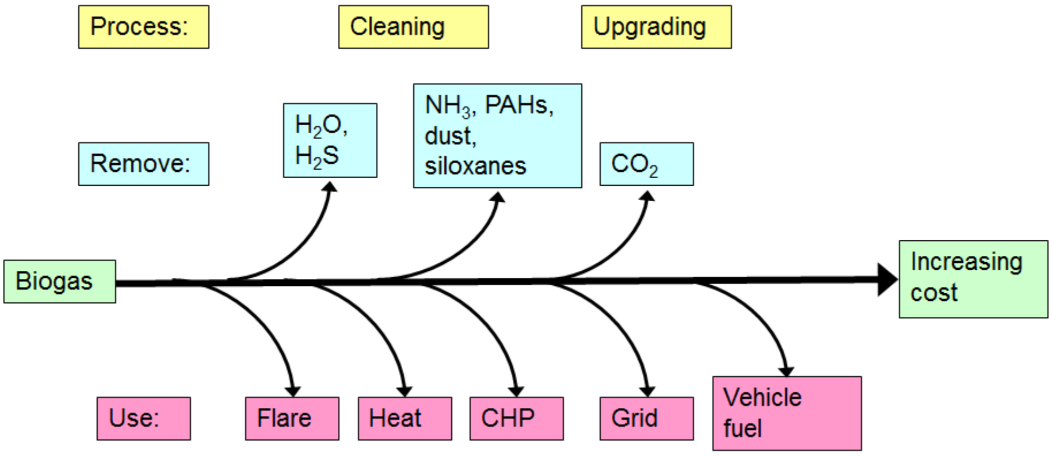

Figure 1: Level of cleaning and upgrading of biogas vs intended use

Standards

Standards across Europe

There is currently no pan-European standard for biomethane, although individual country standards have been put in place. As of the end of 2012, biogas was upgraded to biomethane in 11 European countries, with injection into the gas grid being undertaken in nine of these (Wellinger, 2013). A detailed summary of the standards used in different European countries can be found on the Green Gas Grids website (Green Gas Grids, undated), and a brief overview of those in selected EU countries is presented in Table 2.

In recent years, two EU-funded projects have sought to develop common European standards for biomethane (see Marcogaz (2006) and Huguen P & Le Saux G (2010)), but both failed to reach agreement (Wellinger, 2013). Currently, the Green Gas Grids project is cooperating with the new CEN (European Committee for Standardization) Project Committee, 'Natural gas and biomethane for use in transport and biomethane for injection in the natural gas grid' (CEN TC 408), with the aim of developing a European standard for biomethane. There are two standards under development, as follows:

> CEN TC 408: Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network
>
> - Part 1: Specifications for biomethane for injection in the natural gas network
> - Part 2: Automotive fuel specifications

Further details can be found on the CEN (2009) website. The EU standards (EN 16723-1 and EN 16723-2) are currently in draft format and will become obligatory within six months of the standards being finalised, as mandated by the European Commission (EC, 2010).

Table 2: Comparison of biomethane quality standards in selected EU countries (Organic Resource Agency Ltd., 2011)

Content	UK	Germany	Netherlands	Sweden [a] Biomethane A [b]	Sweden [a] Biomethane B [c]	Austria
Hydrogen Sulphide (mg/m^3)	≤ 5	≤ 5	≤ 5	n/a	n/a	≤ 5
Total Sulphur, including H_2S (mg/m^3)	≤ 50	< 30	45	< 23	< 23	10
Hydrogen (%)	≤ 0.1 (molar)	< 5	12	n/a	n/a	< 4
Oxygen (%)	≤ 0.2 (molar)	< 3	0.5 (3 in dry grid)	< 1	< 1	< 0.5
Wobbe Number (MJ/m^3)	≤ 51.41 and ≥ 47.20	37.80 – 56.52	43.46 – 44.41	47.4 – 46.4	43.9 – 47.3	47.88 – 56.52
ICG (Incomplete combustion factor)	≤ 0.48	n/a	n/a	n/a	n/a	n/a
SI (Soot Index)	≤ 0.60	n/a	n/a	n/a	n/a	n/a

[a] Gas grid is not widely developed in Sweden, the standards for transport fuel use serves as the standard for the injection into the gas grid
[b] Cars with controlled catalytic converter
[c] Cars without catalytic converter

Standards in N Ireland, the UK and ROI

There is currently no injection of biomethane into the gas grid in N Ireland. The regulation of N Ireland's natural gas industry, covering transmission, distribution and supply, is undertaken by the Utility Regulator.

Non-discriminatory access is granted for biogenic gases in Britain, where there are two main sets of regulations for minimum gas quality requirements for grid injection: the Gas Safety (Management) Regulations and the Gas (Calculation of Thermal Energy) Regulations, which are enforced by the HSE and Ofgem respectively (Green Gas Grids, undated).

A quality standard for biomethane injection into the natural gas grid is currently being investigated by Bord Gáis Networks, which operates the gas network in both Northern Ireland and the Republic of Ireland. The Commission for Energy Regulation (CER) in the ROI recently held a consultation on biogas injection into the national gas grid (CER, 2013). The CER is planning to publish a set of directions and decisions in spring 2014, in which target dates will be defined for (among other things) agreeing an interim gas quality specification for biomethane (for grid injection). The specification for Gas Quality is set out in the 'Code of Operations', which is regulated by the CER, under legislative authority (Gas Act and Miscellaneous Provisions Act). This is technically an open specification that can apply to biomethane as it is; however, it is recognised that a few changes are required.

References

Beil M, Hoffstede U (2010). Technical success of the applied biogas upgrading methods. Biogasmax. Available at: http://www.biogasmax.co.uk/downloads/secure/ [accessed 3 February 2014].

CEN (2009). Technical Committees, Workshops and other bodies. European Committee for Standardization. Available at: http://www.cen.eu/cen/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/Pages/default.aspx [accessed 3 February 2013].

De Hullu J, Maassen J, Van Meel P, Shazad S, Vaessen J, Bini L & Reijenga J (2008). Comparing different biogas upgrading techniques. Eindhoven University of Technology and Dirkse Milieutechniek (DMT). Eindhoven, The Netherlands. Available at: http://students.chem.tue.nl/ifp24/BiogasPublic.pdf [accessed March 2009].

EC (2010). Mandate to CEN for standards for biomethane for use in transport and injection in natural gas pipelines. M/475 EN, 8th November 2010. European Commission. Directorate C – New and renewable sources of energy, Energy efficiency and Innovation.

Green Gas Grids (undated). Market Platform Cross-country Overview. Green Gas Grids. Available at: http://www.greengasgrids.eu/market-platform/cross-country-overview.html [accessed 29 January 2013].

Huguen P and Le Saux G (2010). Perspectives for a european standard on biomethane: a Biogasmax proposal. Biogasmax. Available at: http://www.biogasmax.co.uk/downloads/secure/ [accessed 3 February 2014].

Marcogaz (2006). Final Recommendation Injection of Gases from Non-Conventional Sources into Gas Networks. Available at: www.marcogaz.org/ [accessed 18th January 2008].

Oganic Resource Agency Ltd. (2011). An introduction to the production of biomethane gas and injection to the national grid. Available at: http://www.wrap.org.uk/sites/files/wrap/AWM%20Biomethane%20to%20Grid%2005%2007%2011.pdf.

Persson M, Jönsson O, Wellinger A (2006), Biogas Upgrading to Vehicle Fuel Standards and Grid Injection, IEA Bioenergy Task 37 – Energy from Biogas and Landfill Gas, December 2006. Available at: http://www.iea-biogas.net/technical-brochures.html [accessed 3 February 2014].

Petersson A & Wellinger A (2009). Biogas upgrading technologies - developments and innovations. IEA Bioenergy Task 37 - Energy from biogas and landfill gas. Available at: http://www.iea-biogas.net/publicationspublic.htm [accessed January 2010].

Wellinger A. (2013). Standards for biomethane as vehicle fuel and for injection into the natural gas grid. Green Gas Grids. Available at: http://www.greengasgrids.eu/activities/technical-standards.html [accessed 29 January 2013].

Biogas in existing gas-fired electricity generating plants

Contents

Background

This report covers alternative uses of biogas. Biogas used for on-site electricity generation is assumed to be the 'conventional use'. An 'alternative use' of biogas is to upgrade it to biomethane, inject it into the natural gas grid, and use it in existing gas-fired electricity generating stations as a direct replacement for natural gas. As biomethane and natural gas are mixable and interchangeable, no changes in plant set-up are required.

Northern Ireland and the Republic of Ireland share a synchronous power system, the all-island grid (AIG). A single electricity market (SEM) has been in operation in the two jurisdictions since 2007, whereby wholesale electricity is traded on an all-island basis. Some of the statistics presented here therefore relate to electricity generation on an all-island basis, rather than specifically to Northern Ireland.

Why use biomethane in power plants?

The main drivers for the use of biomethane in existing electricity generation plants are outlined as follows.

Greenhouse gas emissions, renewable energy targets and energy security

Energy supply was responsible for 19% of Northern Ireland's greenhouse gas emissions in 2010 (DOENI, 2013). In order to reduce greenhouse gas emissions, targets have been put in place to increase the penetration of renewable sources in this sector. Both Northern Ireland and the Republic of Ireland have set a target for 40% renewable electricity by 2020 (Eirgrid, 2013).

A further reason to increase the use of indigenous sources of renewable energy is the benefit to energy security. This is particularly relevant in Ireland (both ROI and NI), where around 90% of energy needs are met with imported fuels (Eirgrid, 2013), leaving consumers highly susceptible to price fluctuations on global energy markets. Approximately 95% of natural gas in Ireland (ROI and NI) is imported from Britain through the Moffat entry point, while the remaining 5% comes from the Kinsale and Seven Heads gas fields off the coast of Cork (CER & Utility Regulator, 2012).

The Corrib Gas Field, located off the west coast of Ireland, will provide indigenously produced natural gas and is due to commence operation in 2015/16; in time this gas field this may result in reverse flows in the grid from the west coast to the east coast (CER & Utility Regulator, 2012). The Mayo-Galway pipeline, which will serve the Corrib Gas Field, is now operational and could provide the opportunity for biomethane injection points in agricultural areas in the west of the ROI. The planned extension of the gas grid to the west of N Ireland has similar potential.

Power generation accounts for the majority of gas demand in the all-island market; in 2010/11 64% of gas demand on an energy basis was used for power generation (CER & Utility Regulator, 2012). Gas fired generation accounts for 48% of current generation in the all-island fuel mix (Table 1). With almost half of current generation from gas, there is considerable scope for the use of biomethane in existing gas-fired electricity generating plants. This would help to reduce greenhouse gas emissions, increase the penetration of renewables and improve energy security.

Table 1: All-island fuel mix 2012 (CER & Utility Regulator, 2013)

Fuel	%
Gas	47.7
Coal	19.9
Renewables	23.7
- Wind	19.5
- Hydro	3.1
- Landfill gas	0.6
- Biomass	0.5
- Biogas, solar, ocean	>0 each
Peat	6.9
Other	1.8

Intermittency of wind and the need for reliable base load

There has been a significant increase in the level of renewable electricity generation in recent years. In Northern Ireland, 1,164,000 MWh of electricity was from indigenous renewable sources in 2011/12, compared to 128,000 MWh in 2001/02 (DOENI, 2013). The largest share of renewable electricity generation is wind, which in 2012 accounted for 82% of renewable electricity in the all-island fuel mix (Table 1). Wind power, however, does not come without its challenges. It is inherently variable and additional system balancing (Foley et al, 2013) and reliable base load generation are needed in order to maintain a reliable and stable electricity system. Gas plays an important role in meeting these needs. Increasing the use of open-cycle gas plants (OCGTs), fast responsive generators, is one of the strategies for dealing with system balancing on the all-island grid (Foley et al, 2013). Combined cycle gas turbines (CCGTs) are a large provider of base load generation on the all-island grid.

The Joint Capacity Statement issued by the Commission for Energy Regulation (CER) in the ROI and the N Ireland Utility Regulator stated that there will continue to be a substantial demand on gas generation to back-up wind power (CER & Utility Regulator, 2012).

Given the use of gas in peaking plants to balance intermittent supplies and in the provision of reliable base load, there is significant potential for biomethane as a renewable alternative.

Efficiency

To date, biogas utilisation in Northern Ireland has focused on on-site electricity and combined heat and power (CHP) generation. Although CHP plants generally have efficiencies of around 75% (35% electrical and 40% thermal efficiency), a challenge in Ireland is that there are limited markets for heat (Smyth et al, 2010), meaning that such high efficiencies may be difficult to achieve in practice. It can be particularly challenging for rural biogas plants to make full use of the heat, given that, unlike electricity, heat cannot be transported efficiently over long distances and needs to be used close to the generation source. If the heat is not utilised, the overall efficiency of a CHP plant is only around 35%.

Biomethane injected into the gas grid could be used in the existing gas-fired CHP market, where there is likely to already be good utilisation of heat. When it comes to dedicated electricity generation, higher efficiencies can be achieved in larger power plants than in the small-scale plants generally used in biogas installations. CCGT and OCGT power plants typically have efficiencies of 52% to 60% and 35 to 42% respectively. This compares to about 35% electrical efficiency in a small-scale plant, of the type often used at an AD facility. Therefore considering the reliance of the SEM on imported natural gas, there is potential to upgrade the biogas to biomethane standard, and inject it into the gas grid for use in existing gas-fired power plants. Such a strategy could also increase the priority listing of the plant, as it would now be seen as a renewable, as opposed to a fossil fuel, generating station (Smyth et al, 2010).

Potential uses for biomethane in energy supply

The nominal base load capacity of the large generating plant in Northern Ireland is 1564 MW, all of which is from gas-fired power stations (Ricardo-AEA, 2013b). Of the peaking plants, there is nominal capacity of 53 MW from gas-fired OCGT plants, out of a total of 311 MW from OCGTs (Ricardo-AEA, 2013b).

There were 60 CHP plants with a total electrical capacity of 55 MW In Northern Ireland in 2012; 215 GWh of electricity and 487 GWh of heat were generated in the same year, and natural gas accounted for around 37% of the fuel mix, similar to the proportion provided by coal (DECC, 2013).

References

CER & Utility Regulator (2013). Single Electricity Market 2012 All-Island Fuel Mix Disclosure Information Note. 12 July 2013. SEM-13-077. Commission for Energy Regulation (CER) and Utility Regulator NI. Available at: http://www.allislandproject.org/en/project_office_sem_publications.aspx.

CER & Utility Regulator (2012). Joint gas capacity statement 2012. Commission for Energy Regulation (CER) and Utility Regulator NI. Available at: http://www.uregni.gov.uk/news/joint_gas_capacity_statement_2012.

DECC (2013). Combined Heat and Power in Scotland, Wales, Northern Ireland and the regions of England in 2012. September 2013. Department of Energy and Climate Change (DECC). Available at: https://www.gov.uk/government/publications/energy-trends-september-2013-special-feature-articles [accessed 12 December 2013].

DOENI (2013). Northern Ireland Environmental Statistics Report. Department of the Environment Northern Ireland. Available at: http://www.doeni.gov.uk/index/information/asb/statistics/environment_statistics.htm.

EirGrid (2013). Annual Renewable Report 2013. EirGrid and SONI. Available at: http://www.eirgrid.com/media/EirGridAnnualRenewableReport2013.pdf

A.M. Foley, B.P. Ó Gallachóir, E.J. McKeogh, D. Milborrow, P.G. Leahy, Addressing the technical and market challenges to high wind power integration in Ireland, Renewable and Sustainable Energy Reviews, Volume 19, March 2013, Pages 692-703, ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2012.11.039.

Ricardo-AEA (2013b). Envisioning the Future Considering Energy in Northern Ireland to 2050 Sector Annexes – Final Version. Department of Enterprise, Trade and Investment (DETI). Available at: http://www.detini.gov.uk/envisioning-the-future-2.

SMYTH, B. M., SMYTH, H. & MURPHY, J. D. (2010). Can grass biomethane be an economically viable biofuel for the farmer and the consumer? Biofuels, Bioproducts and Biorefining, 4(5), 519-537.

Biogas in agriculture

Contents

Why use biogas in the agricultural sector?

The main drivers for the use of biogas in the agricultural sector are outlined as follows:

Greenhouse gas emissions reduction and meeting renewable energy targets

Agriculture accounted for 26% of Northern Ireland's greenhouse gas emissions in 2010 (DOENI, 2013). The majority of agricultural emissions are from livestock and soils, but a sizeable portion (12%) is from energy use (Ricardo-AEA, 2013).

The emissions from energy use in agriculture (Table 1) can be split into:

- Emissions from stationary combustion (e.g. heating of poultry sheds), which account for around 10% of energy related emissions in agriculture;
- Emissions from off-road machinery (e.g. tractors, harvesters and 4x4 vehicles), which account for around 90% of energy related emissions in agriculture.

Fuel use in agriculture is currently predominantly fossil diesel; in 2012 98% of vehicles in the 'Agricultural Machines' taxation class used diesel fuel (DRDNI, 2013). It is estimated that petroleum products make up 56% of direct energy use in agriculture, with oils for mobile operations accounting for 63% of this. Electricity (when expressed in primary terms) accounts for

33%, gas 11%, and coal 0.4%. Renewables probably account for no more than 0.1% of direct energy use (Park, 2007).

Table 1: Energy use in N Ireland agriculture and related greenhouse gas emissions (Ricardo-AEA, 2013).

Use	Energy use (GWh)[a]	% of total agricultural emissions from energy
Fuel for vehicles (off-road machinery)	1798	90
Fuel for heat (stationary combustion)	200	10
Electricity[b]	198	-

[a] Energy use statistics are for 2010.

[b] Emissions from electricity are categorised under 'energy supply' rather than under 'agriculture'.

For many farms the costs of fuel is a significant input. In the last ten years domestic diesel prices have doubled, whilst those for agricultural diesel, although lower, have tripled (DairyCo, 2014), and the cost of fuel as a proportion of agricultural production costs is a future concern.

Feedstock availability

Many feedstocks suitable for biogas production can be sourced directly from the agricultural sector. Such feedstocks include wastes, such as cattle slurry, poultry litter, pig slurry and slaughter waste, and crops, such as grass and sugar beet. Suitability of feedstock and feedstock potential in Northern Ireland is addressed in more detail by the Feedstocks Working Group.

Fuel and fertiliser costs

Although agricultural prices have followed an upward trend over much of the last 10 years, input costs have risen quicker than farm prices (Allen, 2012). Fuel and fertilisers are significant input costs for the agricultural sector. The costs of both fuel and fertilisers depend on world oil prices, which have been following an upward trend for the last 10 years; in September 2002, one barrel of crude oil cost £17, while in August 2012 the cost had increased by 294% to £67 (Allen, 2012). Biogas produced from on-farm feedstock can be used to meet on-farm energy demand, while digestate from the AD process can be used as a substitute for fossil fertilisers. By sourcing energy and fertiliser from within the agricultural sector, some insulation can be provided to farmers from fluctuations in world oil markets.

Improved waste management

There are around 1.6 million cattle, 0.4 million pigs, 2 million sheep and 19.1 million poultry in Northern Ireland (DARDNI, 2012). This large agricultural sector results in the production of considerable amounts of agricultural waste, including slurry, manure and slaughterhouse waste. The majority of this waste is currently disposed of to land, often leading to air and water pollution. Agricultural policies, including the Nitrates Directive (EEC, 1991), and water and air quality legislation are driving improved waste management practices. AD presents a means of treating many agricultural wastes. Along with biogas, the other product of AD is digestate, which has a lower pollution potential and is more suitable than raw wastes for use as fertiliser (Yiridoe et al., 2009). The environmental benefits of AD of wastes and the value in terms of meeting policy requirements are well documented (Holm-Nielsen et al., 2009).

Potential uses for biogas/biomethane in agriculture

In the agricultural sector, there is the potential to use biogas/biomethane for both stationary combustion and in vehicles. The projects and case studies presented in this section demonstrate the potential for AD to provide farm diversification and commercial opportunities in the agricultural sector in N Ireland.

Stationary combustion

Stationary combustion in the Northern Ireland agricultural sector mainly involves the production of heat for applications such as greenhouses, crop drying and storage, and pig and poultry farming. Biogas (preferably cleaned) can be used directly for heat production and can also be used in a CHP (combined heat and power) plant. The use of biogas for stationary combustion is common in many countries in Europe. Germany, for example, had an estimated 7772 AD plants in 2013, the majority of which were used for heat and/or electricity production (FNR, 2013). Installed electrical capacity in German biogas plants in the same year was 3530 MW, while heat use from biogas plants was 11.3 TWh (FNR, 2013).

Vehicles

For use in vehicles, biogas is upgraded to biomethane (which is the same standard as natural gas). There are a number of biomethane tractors available on the market and under development (Table 2). Research projects include the MEKA, which is a joint research project between Valtra and the Swedish Ministry for Rural Affairs (Valtra, 2013), and the RASE project in England, which is investigating 'the potential and practicalities of farm-sourced renewable fuels and innovative transport technologies' (RASE, 2013).

Small-scale on-farm upgrading technology

Technology for small-scale on-farm upgrading is commercially available. An example is the upgrading technology provided by the Finnish company, Metener Ltd., and distributed in the UK and ROI by Evergreen Gas, a UK-based company. The Metener biogas upgrader uses water as the scrubbing medium and is scaled to upgrade biogas inlet flow rates of between 10 and 30 m^3 per hour. In its standard configuration, the upgrader is installed in a 20' shipping container and is designed to be dropped onto a site, connected to biogas, water and electricity (single phase or 3 phase) and reassembled prior to commissioning. Using this equipment, a 10 m^3/hr inlet flow rate of biogas at 55% methane will produce of the order of 90 kg of vehicle fuel with a purity of 96% methane by volume in a 24 hour period. This is enough fuel to drive a 2 litre-engine vehicle 900 miles or so. 1kg of vehicle fuel is equivalent to approximately 1 litre of diesel, meaning that the operator has the potential to produce the equivalent of around 600 litres of diesel per week. An upgrade unit can either make use of surplus biogas production when a CHP is running at 100% output, or a stream of biogas can be 'side-streamed' through the upgrader so that, although the CHP runs at a slightly lower output, vehicle fuel is produced in addition to heat and electricity (Llewellyn, pers. comm., 2014). Further information on this technology is available on www.evergreengas.co.uk.

Case studies

Some examples of on-farm biogas/biomethane use are presented in Table 3 and Table 4. Another interesting site is in Poundbury, Dorset (see CNG services ltd (undated) for further details). The plant, which opened in 2012, is a joint venture between the Duchy of Cornwall and a group of its tenants, and is the first commercial biomethane-to-gas grid plant in the UK. The plant at Poundbury was the first commercial biogas upgrading plant in the UK, and to date has injected 3 million m^3 of biomethane into the grid with an availability of over 96% (Heat and Power Services Ltd, 2013, pers. comm.). Demonstration sites in N Ireland are described in Tables 5, 6 and 7.

Table 3: Examples of on-farm biogas/biomethane use

Copys Green Farm, Wighton, Norfolk	
In op since	2009
Feedstock	Manure from 100-cow dairy herd and about 100 young-stock (both liquid and solid manures are used, but dry, strawy material is excluded) Whey from the farm's cheese making enterprise Approx. 50 ha of the farm's forage maize crop plus 6 ha of chopped fodder beet
Digester size	$800m^3$ digester
Energy use	230 HP MAN diesel engine 170 kW generator Waste heat from the engine's cooling system is used in the farmhouse and farm office, for grain drying and for cheese making. Some of the heat is needed to warm the digester to maintain gas production levels in cold weather (about 20-25% of total engine heat per year)
Reference	Williams, 2012

Kalmari farm, Laukaa, Finland	
In op since	
Feedstock	Cow manure and confectionery by-products, and in the future will also digest fat trap waste and liquid biowaste. Occasionally smaller amounts of energy crops, mainly grass silage, are also digested.
Digester size	
Energy use	Sisu engine with 25 kW electric and 50 kW thermal capacity 80 kW gas boiler Thermal energy is used for space heating, hot water and in crop drying. Electricity is mainly used on the farm and a small amount is sold to the grid. Electricity 75 MWh/year Heat 150 MWh/year Biomethane for traffic fuel 1000 MWh/year Direct energy use on the farm is generally more profitable than selling, due to transport costs and a relatively low electricity price in Finnish market.
Reference	IEA (2012)

Table 4: Biomethane/CNG tractors

Manufacturer	Details
Valtra	Valtra has developed a dual fuel (diesel/CNG) tractor, based on the N101 tractor (110 HP/81 kW). Enough gas can be stored to allow 3-4 hours' work, with a diesel tank providing additional capacity. 70-80% of the power is generated by gas. Valtra is to begin serial production of biogas tractors in 2013, the first tractor manufacturer to do so. Sources: Agri.EU (2012); Valtra (undated)
Steyr	Steyr has developed two models, a dual fuel tractor and a dedicated CNG tractor. The CVT 6195 was developed as a dual-fuel tractor, reducing diesel costs by approximately 40% and CO_2 emissions by 20%. The Profi 4135 Natural Power has a turbocharged dedicated (mono-fuel) compressed natural gas (CNG) engine. The engine is a 3.0 litre, four-cylinder unit, producing 100 kW/136 HP rated. Market launch is scheduled for the 2015 Sources: NGV (2011); Steyr (2011)
New Holland	New Holland has developed a hydrogen fuel cell tractor. Source: New Holland (2011)

Table 5: Information on Green Farm Energies, Omagh

Green Farm Energies, Omagh	
In op since	2008
Feedstock	Livestock manure (dairy) 4000 t/yr
Digester size	200m^3 digester (1 tank)
Energy use	40 kW generator Electricity production 160,000 kWh/yr Heat production 260,000 kWh/yr Parasitic demands: 7% (remainder exported to grid) All heat is used on site
Reference	Black (pers. comm., 2014)

Table 6: Information on Greenville Rd, Strabane

Greenville Rd, Ardstraw, Strabane	
In op since	April 2012
Feedstock	Initially operated on dairy cattle slurry and grass silage. Approx 10,000 t/yr slurry and 11,000 t/yr silage. Now operating on mostly food waste since securing several waste contracts.
Digester size	2 digesters Each digester is 26 m in diameter and 5 m high (volume 2400 m^3 each).
Energy use	Size of CHP plant/boiler: 2 x 250 kW_e CHP Units Heat/electricity produced per year: 4,000,000+ kW_e and same for heat. Parasitic demands: <10% Most energy is exported >92% availability at 500kW
Reference	Geddis (pers. comm., 2014). Further information is available at: http://www.variablepitch.co.uk/stations/1608/

Table 7: Information on AFBI Hillsborough AD case studies

AFBI Hillsborough (Farm scale research AD)	
In operation since	2008
Feedstock	Cattle slurry & grass silage[1]
Annual quantity	7300 t cattle slurry[2] 443 t grass silage[3]
Digester size	Primary digester 660 m^3 Secondary digester 660 m^3
Nr of tanks	1 Primary digester 1 Secondary digester (used as covered store)
Energy production and use	CHP (Tedom) 23kW nominal electrical output (recently upgraded to 100 kW) Biogas boiler (Hoval) 100kW nominal heat output (used when CHP is not operating)
Electricity & heat produced from CHP per year (slurry only)	167 MWh electricity 313 MWh heat [4]
Electricity & heat produced per year (grass silage and slurry)	319 MWh electricity 602 MWh heat [5]
Parasitic demand (slurry only)	39 MWh electricity 234 MWh heat[6]
Parasitic demand (grass silage & slurry)	39 MWh electricity 239 MWh heat[7]

[1] Cattle slurry was the sole feedstock from January 2009 to July 2011. From August 2011 to Jan 2013 increasing portions of grass silage were added as part of a DARD funded project on co-digestion of grass silage and cattle slurry (Gilkinson & Frost, 2013).

[2] Annual slurry quantities based on an average of 20 t/day from January 2009 to July 2011 (Frost & Gilkinson, 2011).

[3] Grass silage quantities based on the average loading of 1.7 t/day for 5/7 days per week between August 2012-January 2013 (Gilkinson & Frost, 2013).

[4] Estimated annual gross electricity and heat production based on average biogas yields from January 2009 to July 2011 at 27% electricity and 51% heat efficiency in the 23 kW CHP unit operating 8760 hours per annum.

[5] Estimated annual gross electricity and heat production based on average methane yields from August 2012 to January 2013 at 27% electricity and 51% heat efficiency in the 23 kW CHP unit operating 8760 hours per annum.

[6] Estimated annual heat demand based on average of 32 kWh/t slurry input. Estimated electricity demand 5.5 kWh/ t slurry input (Frost & Gilkinson, 2011).

References

Agri.EU (2012). Valtra to start limited serial production of biogas tractors. Agri.EU The Social Network of European Farmers. Available at: http://agri.eu//valtra-to-start-limited-serial-production-of-biogas-tractors-news4325.html [accessed 2 December 2013].

Allen M (2012). Issues affecting the viability of Agricultural businesses in Northern Ireland – Autumn 2012. Research and Information Service Briefing Paper (NIAR 685-12 Paper 46/13). Research and Information Service Briefing Paper. Northern Ireland Assembly. Available at:

http://www.niassembly.gov.uk/Documents/RaISe/Publications/2013/agric_rural_dev/4613.pdf [accessed 2 December 2013].

Black A. (2014). Personal communication with Aaron Black, Southwest College (SWC), N Ireland.

CNG services ltd (undated). Biomethane to grid Poundbury. Available at: http://www.cngservices.co.uk/poundbury/ [accessed 21 January 2014].

DairyCo (2014). Monthly Fuel Price Tracker Published 3 January 2014. Available at: http://www.dairyco.org.uk/market-information/farm-expenses/monthly-fuel-tracker/monthly-fuel-tracker/#.UtM4HLQvm0Q [accessed 9 January 2014].

DARDNI (2012). The Agricultural Census in Northern Ireland Results for June 2012. Department of Agriculture and Rural Development. A National Statistics Publication Crown Copyright. Available at: http://www.dardni.gov.uk/index/statistics/statistical-reports/agricultural-census-ni.htm.

DOENI (2013). Northern Ireland Environmental Statistics Report. Department of the Environment Northern Ireland. Available at: http://www.doeni.gov.uk/index/information/asb/statistics/environment_statistics.htm.

DRDNI (2013). Northern Ireland Transport Statistics 2012-13. Department for Regional Development. Available at: http://www.drdni.gov.uk/ni_transport_statistics_annual_2012-13.pdf [accessed 21 January 2014].

Frost, P., Gilkinson, S. 2011. 27 months performance summary for anaerobic digestion of dairy cow slurry at AFBI Hillsborough Agri-Food Biosciences Institute. http://www.afbini.gov.uk/index/services/services-specialist-advice/renewable-energy-2012/re-anaerobic-digestion.htm

FNR (2013) 'Facts and Figures (Daten und Fakten)', Fachagentur Nachwachsende Rohstoffe (Agency for Renewable Resources), Germany, http://mediathek.fnr.de/grafiken/daten-und-fakten.html, accessed 2 December 2013.

Geddis M (2014). Personal communication with Mark Geddis, Director, Renewables, Williams Industrial Services, Units 5 & 7, Hydepark Commercial Centre, 10 Hydepark Road, Mallusk, Newtownabbey, Co. Antrim, N Ireland.

Gilkinson, S., Frost, P. 2013. Performance summary for anaerobic digestion of dairy cow slurry and grass silage at AFBI, Hillsbough Phase 3 August 2012 – January 2013 Agri-Food and Biosciences Institute. http://www.afbini.gov.uk/index/services/services-specialist-advice/renewable-energy-2012/re-anaerobic-digestion.htm

Heat and Power Services Ltd (2013). Personal communication, 17 December 2013.

HOLM-NIELSEN, J. B., AL SEADI, T. & OLESKOWICZ-POPIEL, P. (2009). The future of anaerobic digestion and biogas utilization. Bioresource Technology, 100(22), 5478-5484.

IEA (2012). Pioneering biogas farming in central Finland. IEA Bioenergy Task 37. Available at: http://www.iea-biogas.net/success-stories.html [accessed DATE].

Llewellyn W (2014). Personal communication with Will Llewellyn, Director, Evergreen Gas Ltd. Barrett's Mill, Ludlow, Shropshire, SY8 4AH.

New Holland (2011). New Holland presents the first NH2™ hydrogen powered tractor ready to go into service on a farm. Press release. 15 November 2011. Available at: http://agriculture.newholland.com/roi/ie/WNH/news/Pages/2011_NH2_news.aspx [accessed 2 December 2013].

NGV (2011). Steyr Presents Dedicated Natural Gas Tractor. NGV Global News. 30 November 2011. http://www.ngvglobal.com/steyr-presents-dedicated-natural-gas-tractor-1130 [accessed 2 December 2013].

Park, N. A. C. S. (2007). Final report to Defra AC0401 : Direct energy use in agriculture : opportunities for reducing fossil fuel inputs. Retrieved from http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=ProjectList&KeywordID=235

RASE (2013). Refuelling the countryside: Sustainable farm and rural transport. Press release. 18 October 2013. Royal Agricultural Society of England. Available at: http://www.rase.org.uk/index.php/news/press-releases/145-re-fuelling-the-countryside-sustainable-farm-and-rural-transport [accessed 2 December 2013].

Ricardo-AEA (2013). Envisioning the Future Considering Energy in Northern Ireland to 2050. Department of Enterprise, Trade and Investment (DETI). Available at: http://www.detini.gov.uk/envisioning-the-future-2.

Steyr (2011). Steyr derives power naturally. Press release. 15 November 2011. Available at: http://www1.steyr-traktoren.com/Pages/en/Aktuelles-Veranstaltungen/Aktuelles/Pressedetail.aspx?Guid=b67da90c-f5dc-45fd-b849-4221962680ee [accessed 2 December 2013].

Valtra (2013). Valtra and Swedish Ministry for Rural Affairs join forces in biogas tractor research. Press release. 13 March 2013. Available at: http://www.valtra.com/news/6329.asp [accessed 2 December 2012].

VALTRA (undated). Research for the future – Valtra biogas tractor. Available at: http://www.valtra.com/news/documents/VALTRA_BIOGAS_EN.pdf [accessed 2 December 2012].

Williams, M (2012). Biogas - the tractor fuel of the future? Farmers Weekly. 18 March 2012. Available at: http://www.fwi.co.uk/articles/18/03/2012/132009/biogas-the-tractor-fuel-of-the-future.htm [accessed 1 December 2013].

YIRIDOE, E. K., GORDON, R. & BROWN, B. B. (2009). Nonmarket cobenefits and economic feasibility of on-farm biogas energy production. Energy Policy, 37(3), 1170-1179.

Biogas in the residential sector

Contents

Why use biogas in the residential sector?

The main drivers for the use of biogas in the residential sector are outlined as follows:

Greenhouse gas emissions

The residential sector was responsible for 19% of Northern Ireland's greenhouse gas emissions in 2010 (DOENI, 2013), with fossil fuel use accounting for 70% of greenhouse gas emissions in the sector (Table 1).

Table 1: Energy use and greenhouse gas emissions in N Ireland residential sector in 2010 (Ricardo-AEA, 2013).

Use	Energy use (TWh)[a]	Greenhouse gas emissions (ktCO2e)
Electricity	3.24	1660
Fossil fuel	14.21	4133
Non-energy	-	123
Total	17.45	5916

[a] Note the original reference lists energy use in GWh instead of TWh.

Renewable energy targets

A target has been set to deliver 10% renewable heat by 2020 (DETI, 2010).

In 2010, the residential sector accounted for 62% of total fossil fuel use for heating in Northern Ireland (Ricardo-AEA, 2012). This compares to 28% in industry and 5% in commercial, the next largest sectors for fossil fuel use in heating (Ricardo-AEA, 2012). Measures to reduce heat use and introduce renewable heat therefore need to be focused on the residential sector (Ricardo-AEA, 2012).

The residential sector is almost entirely dependent on imported fossil fuels. Only 1.7% of heat in Northern Ireland is from renewable sources (DETI, 2011); most of this is from biomass boilers, with a small quantity from heat pumps and solar thermal systems.

Potential of biogas/biomethane to deliver targets

If the target for 10% renewable heat by 2020 were to be met solely by the domestic sector, around 16% of the existing housing stock would be required to switch to renewable heat technologies; this would entail modifying around 11,800 homes per year, which is about 1.6% of the housing stock annually (DETI, 2011). It is estimated that around 7% of boilers are currently replaced each year (DETI, 2011).

About 17% of households in Northern Ireland currently have mains gas heating (NIHE, 2013).

A 2010 study by AECOM/Pöyry (cited in DETI, 2011) estimated that over 15% of Northern Ireland's heat demand could theoretically be met by biogas produced from waste and grass in Northern Ireland.

Thus, indigenous grass and waste biomethane could potentially heat the 15% of households currently with mains gas heating, which is approximately equivalent to the target for 10% renewable heat by 2020.

Existing infrastructure and access to market

Injecting biomethane into the gas grid is an effective means of getting renewable energy to a large number of consumers without any change in existing infrastructure.

Unlike other renewable technologies in the heat sector, biomethane is mixable and interchangeable with natural gas, and has a large, easily accessible customer base. Natural gas was introduced to Northern Ireland in 1996 and there are now about 170,000 households and 12,000 businesses with a gas supply (Utility Regulator, undated). A significantly higher number have access to the gas grid, but are not connected; a recent report for the Consumer Council (Whitty, 2012) stated that 'there are still scores of thousands of properties within a few hundred yards of the existing gas mains network, and about the same within two miles'.

A switch from natural gas to biomethane for existing natural gas customers would not require the installation of a new renewable heating system or any changes in practice; thus the possible higher cost of biomethane can be offset against avoided capital investment (Smyth et al, 2010). In addition, a 'green gas blend' could be sold, whereby the customer could purchase, for example, 10% renewable gas and 90% fossil gas (similar to practices currently in place in the electricity sector). This would allow a higher penetration of biomethane in terms of number of households and the current lower price of natural gas could compensate for the possible higher price of biomethane (Smyth et al, 2010). The gas supplier would need only a change in their billing system.

Information on standards for injection of biomethane into the gas grid is presented in Section 1 of this appendix (Biogas and biomethane: upgrading standards).

Fuel poverty

Fuel poverty is a considerable problem in Northern Ireland and has been on an upward trend since 2004 (NIHE, 2013). Fuel poverty is defined as a household needing to spend over 10% of the household income on all fuel use to achieve a 'satisfactory standard of warmth' (NIHE, 2013). At 42%, the number of households in fuel poverty in Northern Ireland is significantly higher than the 16% in England, the 28% in Scotland (NIHE, 2013), and the 20.5% in the ROI (DCENR, undated)

The high dependence on imported fuels in the residential sector means that Northern Ireland consumers are subject to global price fluctuations beyond the control of DETI or the Northern Ireland Executive (DETI, 2011); this has been highlighted as a contributing factor in fuel poverty in N Ireland (DSDNI, 2011).

Research shows that on average consumers using an oil heating system spend £657/yr more than those using gas (CCNI, 2013). 68% of households in Northern Ireland have oil central heating; a further 7% use dual fuel and, where this is the case, oil is the most common primary source (NIHE, 2013). Not only is heating oil the most expensive fuel and the most damaging for carbon and other emissions, it is also the most prone to energy security concerns and the least regulated fuel (Whitty, 2012).

The Warm Homes Scheme currently in operation in N Ireland offers (among other measures) installation of central heating systems to households on qualifying benefits, where natural gas is the fuel of choice (Warm Homes, undated).

Indigenously produced biomethane could provide a buffer from volatile price changes on global energy markets.

Although penetration of natural gas is currently quite low, the NI Executive has committed to part-fund new gas transmission pipelines to the west of N Ireland, which would provide 34,000 additional business and domestic consumers with lower cost natural gas fuel (NIE, 2013). Construction work is planned to commence in 2015.

Potential uses for biogas/biomethane in the residential sector

Biomethane from gas grid for heating and cooking

Upgraded biogas (biomethane) can be injected into the natural gas grid, and used by households as a direct replacement for natural gas. As biomethane and natural gas are mixable and interchangeable, no changes in household appliances are required.

The IEA Bioenergy task 37 website lists 271 upgrading plants worldwide, of which 159 inject into the gas grid (IEA, undated). In the UK, there are four biogas plants injecting into the gas grid. The UK plants are all relatively new and have only been in operation since between 2010 and 2013, while plants in other parts of the world, such as the USA, Sweden and The Netherlands, have been in operation since the 1980s and 1990s (IEA, undated).

Some examples in the UK include a plant in Didcot, Oxfordshire, where gas derived from the community's sewage is used to heat homes, and a Suffolk brewery that injects biomethane into the national grid (The Wales Centre of Excellence for Anaerobic Digestion, undated).

Biogas used directly for heating, cooking and lighting

Biogas (typically 50-70% methane (CH_4) and preferably cleaned) can be used in the residential sector, either directly from the anaerobic digestion plant, or through distribution in local gas grids. Direct use of biogas in households for cooking, heating and lighting, is common in the developing world.

The drivers for the development of biogas in households in the developing world include the need to improve waste management and the benefits of using a substitute to wood, such as tackling deforestation, improving indoor air quality, and reducing the time spent collecting and carrying fuel, particularly by women and girls.

There are about four million biogas plants in India and around 27 million in China; these are typically small rural plants that use animal wastes as a feedstock (Bond & Templeton, 2011). However, despite the widespread expansion of domestic biogas plants in the developing world since the 1970s, there have been significant problems in some countries due to inadequate maintenance and repair of plants (Bond & Templeton, 2011).

An example of a successful biogas project in the developing world is the SkyLink project in Kenya, which is working to increase the use of biogas systems for cooking in order to tackle deforestation and rural poverty (Ashden, 2010). This project was the recipient of an Ashden Award for sustainable energy.

Micro CHP (using biogas or biomethane)

Micro-CHP is a specific form of CHP designed for apartments and single-family houses. Micro CHP units provide efficient gas central heating and hot water, but also they generate electricity which can be used throughout the home (The Eco Experts, undated) or exported to the national grid. It generates power mainly for consumption in the home.

The amount of electricity that can be generated is dependent on how long the system is running. Once warmed up, a typical domestic system can generate up to 1kW of electricity per hour which, in a typical home, would be sufficient to power appliances and lighting (English Heritage, 2011).

Despite domestic micro CHP systems using fossil fuels (mains gas or LPG as a heating fuel), the technology is referred to as 'low carbon technology' because it is still essentially more efficient than just burning fossil fuels for heat and getting electricity from the national grid (English Heritage, 2011).

Benefits of Micro CHP:

- The electricity generated is used on-site rather than being produced in a power station.
- Any unused electricity can also be sold back to the energy supplier via the Feed in Tariff scheme, where the homeowner is paid a certain amount per kW of electricity fed to the National Grid (Energy Saving Community, undated).
- They are therefore more energy efficient and less carbon dioxide is created. Over its lifetime, a CHP boiler will produce 0.8 tonnes less carbon dioxide that the most energy efficient combination boilers (Energy Saving Community, undated).

Costs of micro CHP units

CHP boilers are not a cheap option. Costing around £5000, they are roughly double the price of a traditional combination boiler, although this depends on the size of the home. (Obviously, larger homes need larger boilers (English Heritage, 2011)). Servicing costs and intervals of every 12 months are similar to a standard boiler (Combined Heat and Power Association, undated).

Micro CHP technologies are still at an early stage of market development and therefore manufactured at limited scale with relatively high upfront costs. Compared with a gas boiler market of around 1.5 million units per annum, micro CHP products cannot compete with economies of scale in production, distribution and installation at current volumes (Ecuity Consulting, 2013), but, with the right market conditions, the cost can be reduced.

In countries like Japan - with around 20,000 domestic micro CHP sales in 2012 - Germany and South Korea, micro CHP technology has been widely supported. Micro CHP prices in Japan were estimated to have dropped by 25% by the end of 2012 compared to 2010 levels (Ecuity Consulting, 2013).

To incentivise consumers to take up micro CHP, financial support is required in order to generate an adequate return. The support for micro CHP under the FIT scheme was recently increased to 12.5p/kWh. However, this is still lower than the support of 17p/kWh deemed essential to deliver a rate of return for consumers (Ecuity Consulting, 2013). This does not apply to N Ireland, where the Renewable Obligation (NIRO) is the scheme that supports Small scale (under 5 MW) generation (Cambridge Economic Policy Associates Ltd, 2011). The NIRO will be not available by 2017. DETI is studying a new proposition to amend the NIRO.Cambridge Economic Policy Associates Ltd. (2011). *Electricity Market Reform Analysis of Policy Options for DETI and NIAUR* (Vol. 5).

Case Study

The Carbon Trust (2011) published a report in 2011, 'Micro-CHP Accelerator'. In this study they try to understand the potential benefits of different micro-CHP technologies and the barriers to their adoption in small and commercial CHP units. The results are shown in Table 2. The main conclusions of the study were:

- A generation tariff of 10p/kWh is not enough for achieving an attractive payback period in micro CHP.
- Micro CHP systems have a simple payback period of 20 years, making them unattractive.
- Manufactures should improve efficiency and reduce costs.

Table 2: Economics of small, commercial micro CHP (Carbon Trust, 2011)

Market assumptions		
Cost of gas (p/kWh)	3.0	
Cost of electricity (p/kWh)	8.0	
Generation tariff (p/kWh)	0.0	
Export tariff (p/kWh)	0.0	
	5 kWhe	**13 kWhe**
Micro-CHP retail price (installed)	£17,000	£50,000
Performance assumptions (based on field trial results)		
Electrical efficiency (%)	22.3	
Thermal efficiency (%)	52.0	
Total efficiency (%)	74.3	
Proportion of electricity exported (%)	3.0	
Gas boiler thermal efficiency (%)	85.5	
Gas boiler electricity consumption (%)	-1.5	
Model results		
Annual heat supplied (kWh)	69,995	181,883
Electricity generated (kWh)	30,000	78,000
Additional gas used (£)	1,581	4,111
Electricity import avoided (£)	2,426	6,308
Electricity export reward (%)	N/A	N/A
Generation reward (£)	N/A	N/A
Net annual saving (£)		
Payback (years)	20.1	22.8

References

Ashden (2010). Case study summary Sky Link Innovators, Kenya. Ashden. Available at: http://www.ashden.org/winners/Skylink10 [accessed 27 January 2014].

Bond T, Templeton MR (2011). History and future of domestic biogas plants in the developing world, Energy for Sustainable Development, Volume 15, Issue 4, December 2011, Pages 347-354, ISSN 0973-0826, http://dx.doi.org/10.1016/j.esd.2011.09.003.

Cambridge Economic Policy Associates Ltd. (2011). *Electricity Market Reform Analysis of Policy Options for DETI and NIAUR* (Vol. 5).

Carbon Trust (2011). Micro CHP (Combined Heat and Power) Accelerator - Final report. Available at: http://www.carbontrust.com/resources/reports/technology/micro-chp-accelerator.

CCNI (2013). Comparative Domestic Cost of Gas v Oil Report. The Consumer Council. Available at: http://www.consumercouncil.org.uk/publications/ [accessed 7 December 2013].

CER (2013). Biogas injection into the Natural Gas Grid. Consultation Paper CER/13/209. Commission for Energy Regulation. Available at: http://www.cer.ie/document-detail/Biogas-Injection-into-the-Natural-Gas-Grid/648.

Combined Heat and Power Association. Micro CHP. Available at: http://www.chpa.co.uk/micro-chp_190.html.

DCENR (undated). Warmer Homes A Strategy for Affordable Energy in Ireland. Department of Communications, Energy and Natural Resources. Available at: http://www.dcenr.gov.ie/Energy/Energy+Efficiency+and+Affordability+Division/Affordable+Energy.htm [accessed 27 January 2013].

DETI (2011). Consultation Energy The Development of the Northern Ireland Renewable Heat Incentive. Department of Enterprise, Trade and Investment (NI). Available at: http://www.detini.gov.uk/the_development_of_the_northern_ireland_renewable_heat_incentive.pdf.

DETI (2010). Energy A Strategic Framework for Northern Ireland. Department of Enterprise, Trade and Investment (NI). Available at: http://www.detini.gov.uk/deti-energy-index/deti-energy-strategic-energy-framework.htm, accessed 6 August 2012.

DOENI (2013). Northern Ireland Environmental Statistics Report. Department of the Environment Northern Ireland. Available at: http://www.doeni.gov.uk/index/information/asb/statistics/environment_statistics.htm.

DSDNI (2011). Warmer Healthier Homes A New Fuel Poverty Strategy for Northern Ireland. Department for Social Development. Available at: http://www.dsdni.gov.uk/warmer-healthier-homes.pdf.

Energy Saving Community. Combined Heat and Power (CHP). Available at: http://www.energysavingcommunity.co.uk/combined-heat-power-chp.html.

English Heritage (2011). Small scale combined heat and power (CHP). 2011. Available at: http://www.climatechangeandyourhome.org.uk/live/small_scale_combined_heat_and_power.aspx.

Green Gas Grids (undated). Market Platform United Kingdom Technical standards for biomethane and natural gas. Available at: http://www.greengasgrids.eu/market-platform/united-kingdom/technical-standards.html [accessed 27 January 2014].

IEA (undated). Up-grading Plant List. IEA Bioenergy Task 37. Available at: http://www.iea-biogas.net/plant-list.html [accessed 8 December 2013].

NIE (2013). Foster welcomes Executive support for extension of the natural gas network. January 2013 news releases, Monday, 14 January 2013. Available at: http://www.northernireland.gov.uk/index/media-centre/news-departments/news-deti/news-deti-140113-foster-welcomes-executive.htm [accessed 27 January 2014].

NIHE (2013) Northern Ireland House Condition Survey 2011 Main Report. Northern Ireland Housing Executive. Available at: http://www.nihe.gov.uk/index/corporate/housing_research/house_condition_survey.htm

Ricardo-AEA (2013). Envisioning the Future Considering Energy in Northern Ireland to 2050. Department of Enterprise, Trade and Investment (DETI). Available at: http://www.detini.gov.uk/envisioning-the-future-2.

SMYTH, B. M., SMYTH, H. & MURPHY, J. D. (2010). Can grass biomethane be an economically viable biofuel for the farmer and the consumer? Biofuels, Bioproducts and Biorefining, 4(5), 519-537.

The Eco Experts. Micro CHP. Available at: http://www.theecoexperts.co.uk/micro-chp.

The Wales Centre of Excellence for Anaerobic Digestion (undated). Gas Utilisation. Retrieved from http://www.walesadcentre.org.uk/Technologies/GasUtilisation.aspx

Utility Regulator (undated). Market Overview. Utility Regulator. Available at: http://www.uregni.gov.uk/gas/market_overview/ [accessed 7 December 2013].

Warm Homes (undated). What Will I Get? Department for Social Development. Available at: http://www.warm-homes.com/What-Will-I-Get.aspx [accessed 27 January 2014].

Whitty, Lord (2012). Energising Northern Ireland An Independent Report by Lord Whitty for the Consumer Council. Retrieved from http://www.consumercouncil.org.uk/filestore/documents/Lord_Whitty_Report.pdf

Biogas as a Transport Fuel

Contents

Abbreviations

AD	Anaerobic Digestion
BMEP	Brake mean effective pressure
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
conc.	Concentration
EU	European Union
GHG	Greenhouse gas emissions
GJ	Giga Joules
ha	hectare
HC	Hydrocarbons
HDVs	heavy-duty vehicles
ILUC	Indirect land use change
km	kilometre
Kt	kilo tonnes
LBM	liquid biomethane
LDVs	light-duty vehicles,
LNG	Liquefied natural gas
Max.	Maximum
MDVs	medium-duty vehicles
NG	Natural gas
NGV	natural gas vehicles
NI	Northern Ireland
NMHC	non-methane hydrocarbons
NMHCs	non-methane hydrocarbons
NOx	Nitrogen oxides
OEM	original equipment manufacturer
PAHs	Polycyclic aromatic hydrocarbons
PM	particulate matter
PM	Particulate matter
rpm	revolutions per minute
SO_2	Sulphur dioxide
t	tonnes
THC	Total hydrocarbon
UK	United Kingdom
vol	volume
yr	year

Introduction

Anaerobic digestion (AD) is a process that converts organic material (specially wet material as slurries, manure, food waste, crop residues, etc.) - in the absence of oxygen - into methane, carbon dioxide and other gases in minor quantities. Biogas is mainly burned to generate electricity and heat. Biogas need to be cleaned up to the standards of the natural gas before it can be used as a road transport, in other words, it needs to be upgraded and it is called biomethane. Biomethane is a fuel that can be catalogued as renewable. It is the scope of this report to study the use of biomethane as a transport fuel in Northern Ireland.

Legislation

The European Union (EU) is committed to producing energy in a sustainable manner. The EU community recently introduced the Renewable Energy Source Directive 2009/28/EC which requires a 20% share of renewable energy sources in final energy consumption in each member state by 2020. Directive 2009/28/EC allows individual member states to decide how to achieve the target through electrical and thermal renewable energy utilisation. The Directive also requires a 10% share of renewable fuels in the transport sector by 2020 [1].

In October 2012 the EU published a proposal to minimise the climate impact of biofuels, by amending the current legislation on biofuels through the Renewable Energy and the Fuel Quality Directives. In particular, the proposals suggest [2]:

- To increase the minimum greenhouse gas saving threshold for new installations to 60%.
- To include indirect land use change (ILUC) factors in the reporting by fuel suppliers and Member States of greenhouse gas savings of biofuels and bioliquids [3];
- To limit the amount of food crop-based biofuels and bioliquids that can be counted towards the EU's 10% target for renewable energy in the transport sector by 2020 [3];
- To provide market incentives for biofuels with no or low indirect land use change emissions, and in particular the 2nd and 3rd generation biofuels produced from feedstock that do not create an additional demand for land, including algae, straw, and various types of waste, as they will contribute more towards the 10% renewable energy in transport target of the Renewable Energy Directive [3]. The proposal includes a list of feedstocks that would count for either the 4-fold or 2-fold multiple counting. Among those that would be quadrupled are algae, straw, animal manure, sewage sludge, bagasse, and other non-food crop residues. The feedstocks that would count double are used cooking oil, certain animal fats, non-food cellulosic material, and lignocellulosic material except saw logs and veneer logs [4].

Benefits of Using Biogas in Transport

The utilisation of biogas as vehicle fuel uses the same engine and vehicle configuration as natural gas (NG). In total there are more than 17 million natural gas vehicles [5] (NGV) all over the world; this demonstrates that the vehicle configuration is not a problem for use of biogas as vehicle fuel. However, the gas quality demands are strict. With respect to these demands the raw biogas from a digester or a landfill has to be upgraded. Removal of CO_2 will be required if the biogas needs to be upgraded to natural gas standards or vehicle fuel use. It dilutes the energy content of the biogas but has no significant environmental impact [6]. Table 1 compares the characteristics of different gas fuels.

Table 1 Characteristics of different gas fuels [6]

Parameter	Unit	Natural Gas	Town Gas	Biogas (60% CH_4, 25% CO_2, 2% Other)
Calorific value (lower)	MJ/m^3	36.14	16.1	21.48
Density	kg/m^3	0.82	0.51	1.21
Wobbe index (lower)	MJ/m^3	39.9	22.5	19.5
Max. ignition velocity	m/s	0.39	0.70	0.25
Theoretical air requirement	m^3 air/m^3 gas	9.53	3.83	5.71
Max. CO_2 conc. in stack gas	Vol%	11.9	13.1	17.8
Dew point	°C	59	60	60-160

The benefits of using biogas as a transport fuel after upgrading are [6,7]:

- has a higher calorific value in order to reach longer driving distances;
- has a regular/constant gas quality to obtain safe driving;
- does not enhance corrosion due to high levels of hydrogen sulphide, ammonia and water;
- does not contain mechanically damaging particles;
- does not give ice-clogging due to a high water content;
- has a declared and assured quality;
- Upgraded biogas is actually the cleanest vehicle fuel possible with respect to environment, climate and human health;
- Biogas is a CO_2 neutral fuel;
- reduced emissions from transport;
- reduced reliance on foreign fossil fuel supplies;
- less noise emissions;
- less unpleasant odours;
- less emissions from fertilizer production;
- less methane leakage;
- Increased safety. Accident statistics from countries with a high proportion of gas-powered cars such as Italy, Argentina, USA, Canada and New Zealand show that gas as a fuel is safer than petrol or diesel. The ignition temperature of gas (650 ^{o}C) is appreciably higher than that of petrol (300 ^{o}C). In addition, the danger of a gas bottle rupturing in an accident is virtually non-existent;
- Image and social benefits for 'being seen to be green'.

Forms of Biomethane

Compressed natural gas (CNG) is NG that is stored under high pressure. Normally, CNG is stored in high pressure tanks at 21–25 kPa (3,000–3,600 psi). CNG is the form of NG most commonly used in vehicles [8].

Liquefied natural gas (LNG) is stored in small volume tanks by purifying NG and condensing it into a liquid by cooling it to below -162 °C. Under normal conditions, LNG occupies 1/600 of the volume of NG. It must be kept at very cold temperatures to remain in liquid form, so it is typically stored in a double-wall vacuum-insulated pressurized tank. Because of the difficulties of storing and managing LNG, it is only used as a vehicle fuel in heavy-duty, high fuel-demanding vehicles such as highway trucks and construction equipment [9].

Available gas vehicles

NG can cover almost the whole spectrum of vehicles, ranging from motorcycles, tuk-tuks, cars, vans, buses, trucks, off-road vehicles, ships and trains, including even airplanes. The most common form of use: road transportation as light-duty vehicles (LDVs), medium-duty vehicles (MDVs) and heavy-duty vehicles (HDVs). Generally, CNG is more commonly used for LDVs while HDVs require more energy to run and tend to use LNG to maintain an acceptable range [10].

CNG vehicles are relatively common in several countries. Approximately 17,730,433 [5] CNG vehicles concentrated to Argentine, Pakistan, Brazil, India, Iran and Italy are on the road today. Over 800,000 of these CNG vehicles operate in Europe [11]. Table 2 shows the number of NGV in some countries and total in the world. In the UK 0 % of the cars use NG and also contributing to 0% worldwide, this percentage is very low when compared to Pakistan, Argentina and Italy which has 15.74 %, 17.53 % and 4.77 % respectively of natural gas vehicles (NGV) in the world.

Light-duty vehicles

The overall availability of original equipment manufacturer (OEM) LDVs on NG has improved over the past years with vehicle manufacturers such as Fiat, Volkswagen, Mercedes-Benz, Opel, Renault, Citroën, Peugeot, as well as several Asian manufacturers adding CNG (bifuel) models to their product range. The difference in between the retail price of an OEM LDV running on NG versus a similar model running on petrol or diesel is an important parameter in the market development of NGVs. In many countries with successful NGV markets, the price differential for consumers has been reduced through subsidies, tax exemptions, etc. While the premium for an NGV varies widely from country-to-country, based on data obtained through the IGU questionnaires in 2009, there is an average price difference of € 1 956 for an NGV versus its petrol equivalent. The overall availability of OEM LDVs on NG has improved over the past years The overall availability of OEM LDVs on natural gas has improved over the past years [10].

Medium- and heavy-duty vehicles

In most countries and regions, the availability of MD/HD-NGVs is no longer a bottleneck in the market development of NGVs. Buses operating on natural gas are widely available, and recent developments (e.g. high-pressure direct injection dual-fuel engines) have improved the availability of natural gas trucks. Manufacturers currently offering natural gas HDVs include Mercedes, Iveco, Ford, Volvo, MAN, Isuzu, Nissan as well as numerous Chinese manufacturers [10].

Heavy-duty applications of NGVs include a large variety of vehicles, such as buses, trucks, garbage trucks, port vehicles, off-road vehicles, forklifts, tractors and other agricultural vehicles, and even "exotic" applications such as ambulances, fire trucks and 150 tonne road-trains for long-haul transport in the Australian outback. The most common application differs from region to region: buses in Asia and Europe; agricultural vehicles on natural gas in Russia and the CIS. Medium-duty vehicles (3.5-12 tonnes) include delivery vans and smaller versions of buses and trucks. Although data on price differences is scarce, the typical additional cost for an HDV running on natural gas in comparison to its diesel counterpart lies in the range of €30 000 to € 35 000, although this varies from country-to-country. Conversion costs vary widely, but tend to be in the order of magnitude of half of the price premium on an OEM vehicle [10].

Distribution and fuelling stations

In countries with an existing natural gas grid such as the UK, Italy and Germany, biomethane can be distributed via the existing pipe-line infrastructure together with natural gas, the so called ''green gas concept''. Furthermore, the transmission lines for natural gas operate at a relatively high pressure (up to 80 bar where as local distribution grids operate at a substantially lower pressure (4 – 30 bar) [11].

Some countries like Sweden, Switzerland, Germany and France have a standard for injecting biogas into the natural gas grid. The standards have been set to avoid contamination of the gas grid or end use. Demands on Wobbe index have been set to avoid influence on gas measurements and end use. In the standards there are limits on certain components for instance sulphur, oxygen, particles and water dew point. These demands are in most cases possible to achieve with existing upgrading processes. In some cases landfill gas can be difficult to upgrade to sufficient quality due to large content of nitrogen [12] or enrichment with propane to match the calorific value and combustion stability of natural gas may also be necessary. For health & safety considerations, an odorant is usually added to give the biogas a characteristic smell [13].

Table 2 NGVs, fuel consumption and refuelling Stations in some Countries and the total Worldwide Adapted from Natural and Biogas Vehicle Association [5]

Country	Natural Gas Vehicles								Monthly gas consumption (M Nm3)			Biomethane	CNG stations					L-CNG stations	LNG stations	All stations
	Total NGVs	LD+MD +HD Vehicles	LD Vehicles	MD+HD Buses	MD+HD Trucks	Other	% of total LD+MD+HD vehicles in the country	% of total NGVs worldwide	Reported consumption	Theoretical consumption	Ratio	Share	Total	Public	Private	Planned	% of total CNG stations worldwide	Total	Total	Total
Argentina	2,244,346	2,244,346	2,244,330	0	16	0	17.53%	12.66%	216.97	404.03	54%	0%	1,916	1,916	0	0	8.65%	0	0	1,916
Brazil	1,743,992	1,743,992	1,743,992	0	0	0	4.97%	9.84%	141.60	313.92	45%	0%	1,793	1,793	0	0	8.09%	0	0	1,793
Finland	1,239	1,215	1,150	50	15	24	0.03%	0.01%	0.32	0.40	78%	25%	19	18	1	4	0.09%	0	0	19
France	13,538	13,538	10,000	2,493	1,045	0	0.04%	0.08%	6.00	12.41	48%	3%	144	35	109	3	0.65%	0	0	144
Germany	96,349	96,293	94,707	1,496	90	56	0.20%	0.54%	23.00	21.81	105%	20%	915	844	71	85	4.13%	0	0	915
Hungary	4,062	4,060	4,000	50	10	2	0.12%	0.02%	0.22	0.90	24%	2%	18	3	15	8	0.08%	0	0	18
Iceland	918	918	900	2	16	0	0.42%	0.01%	0.17	0.22	79%	100%	2	2	0	2	0.01%	0	0	2
India	1,500,000	1,493,095	1,469,004	23,376	715	6,905	3.53%	8.46%	163.21	337.32	48%	0%	724	405	319	0	3.27%	0	0	724
Iran	3,300,000	3,300,000	3,293,948	6,036	16	0	27.09%	18.61%	480.00	611.07	79%	0%	1,992	1,957	35	508	8.99%	0	0	1,992
Italy	846,523	846,523	843,023	2,300	1,200	0	2.07%	4.77%	75.00	162.24	46%	0%	959	912	47	0	4.33%	7	0	966
Netherlands	6,680	6,677	5,650	686	341	3	0.07%	0.04%	0.00	4.10	0%	50%	186	119	67	30	0.84%	1	7	194
Norway	877	876	353	514	9	1	0.03%	0.00%	1.60	1.63	98%	10%	24	21	3	5	0.11%	3	0	27
Pakistan	2,790,000	2,610,000	2,609,500	500	0	180,000	79.67%	15.74%	245.75	487.41	50%	0%	2,997	2,997	0	0	13.52%	0	0	2,997
Sweden	44,321	44,319	41,820	1,851	648	2	0.92%	0.25%	11.70	15.02	78%	60%	195	138	57	0	0.88%	4	8	207
Switzerland	11,058	10,998	8,126	2,572	300	60	0.24%	0.06%	1.61	10.08	16%	23%	138	133	5	3	0.62%	1	0	139
United Kingdom	559	519	20	3	496	40	0.00%	0.00%	3.00	1.50	199%	0%	9	1	8	4	0.04%	9	13	31
USA	250,000	250,000	231,400	14,600	4,000	0	0.10%	1.41%	77.52	97.45	80%	0%	1,438	535	903	0	6.49%	0	46	1,484
NGV world countries	**17,730,433**	**17,459,501**	**16,310,105**	**781,396**	**368,000**	**270,932**	**1.64%**	**100.00%**		**6,408.39**			**22,162**	**19,779**	**2,383**	**1,787**	**100.00%**	**441**	**1,433**	**24,036**

* LD (Light Duty), MD (Medium Duty), HD (Heavy Duty)

Notes:

The column 'theoretical monthly consumption' is calculating total monthly consumption if cars consume 180, buses 3000, trucks 3000, and other vehicles 90 Nm3 per month

There is a huge difference between different truck types. A 44 ton truck in long distance road transport, or HD urban trucks and buses in intensive use may consume up to 8000 Nm3 per month.

The final column compares this number with the reported consumption (if available), otherwise shown as 0 %. Figures far below 100 % might indicate that the true fleet of vehicles is lower than reported, or that vehicles reported as trucks or buses are in fact light/medium duty vehicles. Theoretical values of less than 50% or more than 200% of reported values are an indication of outliers.

Probable magnitude of annual world consumption of methane gas used as a vehicle fuel

	Billion Nm3	TWh	PJ	Mtoe	%
Total	**76.9**	**738**	**2658**	**63.5**	**100.0**
Cars	**35.2**	**338**	**1218**	**29.1**	**45.8**
Buses	**28.1**	**270**	**972**	**23.2**	**36.6**
Trucks	**13.2**	**127**	**458**	**10.9**	**17.2**
Other	**0.3**	**3**	**10**	**0.2**	**0.4**

Note: Rough estimates due to lack of precise data in many markets

Nm3	Normal cubic metre
TWh	Terawatt hours (10^{12} *Watthours)*
PJ	Petajoule (10^{15} *Joules)*
Mtoe	Million tonnes of oil equivalent

However, the technology for injecting biomethane into the natural gas grid to be used as fuel for vehicles has been introduced in many countries, for example in Germany and Finland [14], injection of bio-methane derived from AD into the gas grid is still in its infancy in the UK. The UK is ideally suited for this technology since it has a good distribution infrastructure with a dense coverage [13]. Table 3 shows a list of the fuelling stations (CNG and LNG) in operation in the UK at the moment.

Table 3 CNG and LNG fuelling stations in the UK [15] (Com: commercial; Demo: Demonstration)

Compressed Natural Gas – Mains NG Fed			
Operator	**Location**	**Fills**	**Type**
CNG Services	Crewe M6, Junction 15	HGV & Mother (500 HGV Cap)	Com
Gas Bus Alliance	Beccles	Daughter Fill Buses	Com
Gas Bus Alliance	Darlington	Daughter Fill Buses	Com
Gas Bus Alliance	Reading	Daughter Fill Buses	Com
Gas Bus Alliance	Runcorn	Daughter Fill Buses	Com
Tenens	Boston	Tenens	Com
Tenens	London (Aveley)	Tenens	Com
Tenens	Swindon	Tenens	Com
Gasfill 2000	Multiples	Single vehicle, 2m^3/h, 1.5 kg/h	Com
BGE Demonstration	Ireland	2 – 10 LGV	Demo
BG Demonstrations	GB Various, 2000 – 2006	Mothballed	Demo
Compressed Natural Gas – AD Biogas			
Operator	**Location**	**Fills**	
Leeds Council	Leeds Waste	2 Bin Lorries, LBNG, £150k	Demo
Sheffield Council	Sheffield	Demonstration	Demo
Liquid Natural Gas			
Operator	**Location**	**Fills**	
Chive Fuels	A1(M); J51 (Londonderry)	All	Com
Chive Fuels	M1; J9 (Flamstead) J23 (Shepshed)	All	Com
Chive Fuels	M6: J11 (Wolves), J20 (Lymm), J38 (Tebay)	All	Com
Chive Fuels	M48: J1 (Aust/Bristol)	All	Com
Chive Fuels	M62; J31 (Castleford)	All	Com
Hardstaff (Portal)	Nottingham	2 Dispensers & LNG tanker fleet	Com
Linde (BOC)	Mobile	Single Dispenser Skids – Trials	Demo
Linde (BOC)	Static	Single dispenser Fleet based	Com

Cost of biomethane as a fuel

The cost of the fuel itself is significantly less than conventional fuels. A 675 vehicle refuse truck fleet study in Madrid showed that the fuel costs were in the region of 30 % lower than the diesel alternative. The same study showed that during the complete truck life, including investments for CNG refuelling equipment and the trucks extra costs, an overall saving of 15 % was achieved when compared to the diesel alternative. CNG vehicles have numerous components that are similar to those of a traditional vehicle; so much of the maintenance costs will be similar to diesel or petrol vehicles. The main differences are engine oil and spark plugs, which are changed less often as natural gas is a clean burning fuel and produces comparatively little by-products of combustion [16]. Figure 1 shows a comparison of the cost of distribution and dispensing of biomethane at medium scale.

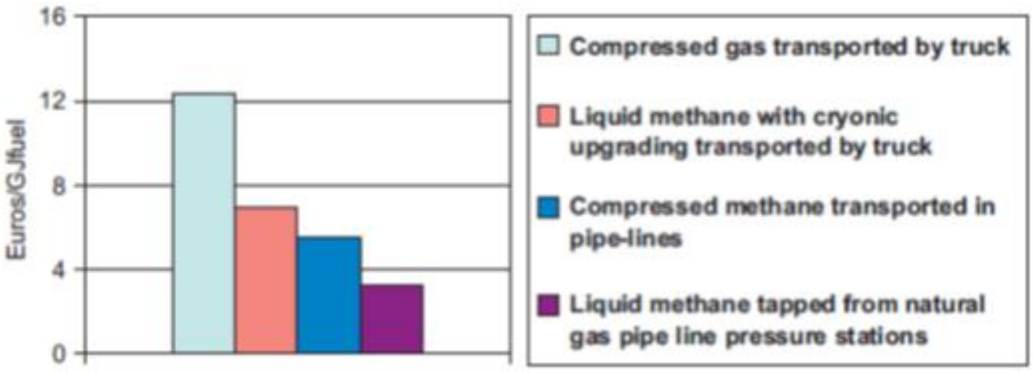

Figure 1 Cost of Distribution and dispensing of biomethane at medium scale [11].

At the conference Biomethane for Transport, Bart Bonsall [17] showed the gap between the cost of NG and biomethane (Figure 2), being the last one more expensive, it could overwhelm the NG demand for biomethane having a higher cost. He suggested that the market barriers can be overcome by using EU experience that indicates 25 % discounts will attract early market uptake, as well as the international developments will keep the gap between low NG price and diesel price to remain stable in future. This perceived stability and reliability of NG will overcome inertia, promoting confidence & uptake in gaseous fuels as shown in Figure 2. Table 4 shows an example of a market development strategy for CNG.

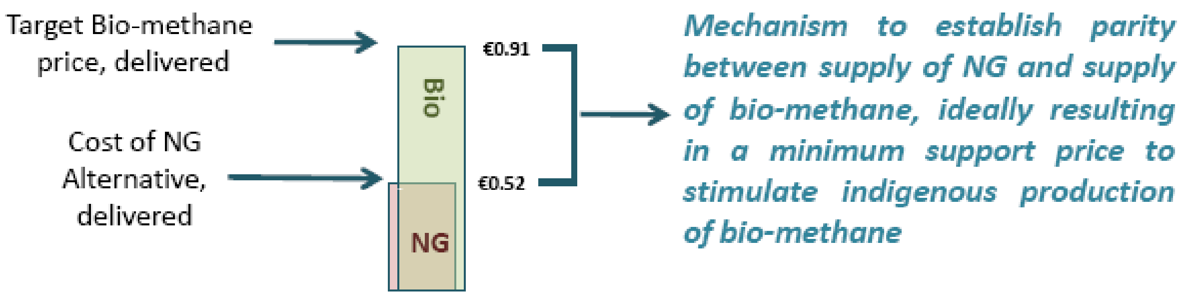

Figure 2 Mechanism to facilitate Market Development of Biomethane [17]

Table 4 Market Development Strategy for CNG [17]

	Euro's
Example Diesel Price – retail consumers (incl VAT)	€1.50
Ex Vat Diesel Price @ 23 % VAT	€1.22
Less: Hauliers Fuel Rebate	0.07
Example Diesel Price – to hauliers (ex VAT)	1.14
Target discount for gaseous fuel price to hauliers (ex VAT)	25%
Comparable gaseous fuel price to hauliers (ex VAT)	€0.91
Comparable gaseous fuel price - retail (ex VAT)	€1.13

Assumption: 1m^3 NG (bio or fossil) = 1 litre diesel equiv. energy value

Efficiency of biogas as a transport fuel

It is estimated that if Europe was to maximise its potential for using biogas as a transportation fuel, biogas could replace up to 15 – 20 % of all fossil transportation fuels [7]. Table 5 shows the energy yield and the annual mileage of different biofuels, biomethane from grass has a high energy yield of 134 GJ/ha/yr and 51,860 km/ha with the benefit that is doesn't required arable land.

Table 5 Energy Yield and annual mileage of various biofuels

Biofuel	**Energy yield** [18,19,20] Gross GJ/ha/yr	Net GJ/ha/yr	**Mileage per ha** (calculations based on net energy) [21] km/ha	**Area rqd per car** ha/car	**Notes**
Wheat ethanol	66	4	1,860	8.98	Requires arable land, grown in rotation (therefore larger area required under contract)
Soybean biodiesel	23	8	3,721	4.49	"
Rapeseed biodiesel	46	25	11,628	1.44	"
Corn ethanol	70	38	17,674	0.95	"
Wheat ethanol (with WDGS biomethane)	84	43	20,000	0.84	"
Wheat biogas	81	47	21,860	0.76	"
Sugarbeet ethanol	105	51	23,721	0.70	"
Palm oil biodiesel	120	74	34,419	0.49	Tropical crop
Grass biomethane	122	78	36,279	0.46	Does not require arable land, not grown in rotation
Sugarbeet biomethane	134	90	41,860	0.40	Requires arable land, grown in rotation (therefore larger area required under contract)
Sugarcane ethanol	135	120	55,814	0.30	Tropical crop

Emissions

The principal environmental benefit of biomethane as a vehicle fuel relates to the greenhouse gas reductions compared to fossil fuels. Throughout the lifecycle of biomethane there both emission sources and sinks that balance to create a net reduction in greenhouse gas emissions compared to diesel. This is due to biomethane capturing emissions from decomposing organic materials, the CO_2 emitted is considered to be part of the natural carbon cycle and no net increase in greenhouse gas emissions occur [22] .Therefore the large scale implementation of biogas as a transport fuel can greatly reduce national carbon dioxide emissions, and aid the meeting of Kyoto obligations [7].

As well a reduction in greenhouse gas emissions that result from the biomethane life cycle, the chemical composition of methane dictates that, compared to petrol or diesel, there is a decrease in carbon emissions for the same energy release. A reduction in greenhouse gas emissions is therefore achieved when petrol/diesel is replaced with natural gas, not just when replaced with biomethane.

Other emissions

While biomethane and natural gas clearly result in reductions in carbon emissions when compared to petrol and diesel, the levels of other engine-out emissions can be difficult to quantify as they are highly dependent on engine parameters, such as ignition timing, capacity, performance, air-fuel ratio and level of stratification.

A review of the literature was carried out to obtain typical emission values for diesel, petrol, dual-fuel, bi-fuel and dedicated CNG engines (Table 6, Table 7, Table 8). Dual fuel engines are those that run on a combination of diesel and CNG, while bi-fuel engines run on either petrol or CNG. No comparative studies covering diesel, petrol, dual-fuel, bi-fuel and dedicated CNG engines were found in the literature. Caution must therefore be exercised when viewing the information in Tables 1, 2 and 3. The tables were created using data from different studies (which used different equipment and operating conditions) and the tables cannot therefore be accurately compared to each other. For a true comparison of fuels, back-to-back testing of engines under the same operating conditions is required. A brief overview of other findings in the literature is given in the following paragraphs.

Nitrogen oxide (NO_x)

Without measures to reduce exhaust emissions (such as lean-burn operation or stoichiometric combustion in combination with a three way catalyst), emissions of NO_x from gas engines can be higher than from diesel engines [27]. However, NO_x emission reducing technologies are currently employed in heavy-duty natural gas vehicles, and a Finnish study found that NO_x emissions for CNG vehicles generally follow the Euro certification class, as do the corresponding diesel vehicles [27]. The type of CNG engine influences the NO_x emissions. Lean-burn CNG engines are not necessarily better than diesel engines, but CNG engines operating at stoichiometric air fuel ratio have been shown to have NO_x levels 75% below Euro 3 diesel levels [27]. Other studies showed reduction in NO_x emissions for a CNG compared to diesel engine of 56% [28], 98% [29] and 49% [30]. An investigation conducted by the Swiss Federal Office of the Environment found a 53% reduction in NO_x in vehicles fuelled by natural gas compared with petrol-fuelled passenger cars, and an 85% reduction compared to diesel-powered heavy goods vehicles [7]. As with any fuel type, exhaust after-treatment technology for compressed natural gas engines has to be developed to reduce emissions to legislated tail-pipe levels.

Table 6 Emissions[a] from a typical dedicated natural gas engine [23, 24]

	NO_x (g/kWh)	HC[b] (g/kWh)	CO_2 (g/kWh)	CO (g/kWh)	PM[c] (g/kWh)
Dedicated CNG	1.79	0.02	526	0.65	0.0140

[a] Tail-pipe emissions; [b] HC: Hydrocarbons; [c] PM: particulate matter

Table 7 Measured emissions [a] for a diesel/dual fuel research engine [25]

	NO_x (g/kWh)	HC (g/kWh)	CO_2 (g/kWh)	CO (g/kWh)	PM (mg/l)
Diesel	5.90	2.00	825	8.00	0.12
Dual fuel	2.75	21.00	973	28.00	0.01
Dual fuel % change from diesel	-53	950	18	250	-91

[a] Engine-out emissions. Information taken at 2000rpm, 3.7bar BMEP and 80% energy substitution from gas

Table 8 Measured emissions [a] for a bi-fuel automotive engine [26]

	NO_x (g/kWh)	HC (g/kWh)	CO_2 (g/kWh)	CO (g/kWh)
Petrol	14.24	6.64	981	35.43
Bi fuel CNG	9.82	3.99	801.02	16.27
Bi fuel CNG % change from petrol	-31	-40	-18	-54

[a] Engine-out emissions. The test conditions were as follows. For petrol: 1999 rpm, 3.6 bar BMEP, equivalence ratio 0.99. For bi-fuel: 2111 rpm, 3.68 bar BMEP, equivalence ratio 0.99.

Particulate matter (PM)

Natural gas gives soot free combustion and emissions from natural gas engines have very low particulate emissions. A study on five different buses (three diesel, two CNG) in Finland showed PM emissions of 0.005 and 0.01 g/km for the CNG buses, while much higher emissions of between 0.02 and 0.17 g/km were recorded for the diesel buses [27]. A study carried out in Italy comparing the emissions from a CNG spark-ignition heavy-duty urban bus engine (with a three-way catalyst) with an equivalent diesel fuelled engine showed that the CNG engine emissions were more than 30 times lower for PM [29]. Typical PM emission reductions in a CNG bus compared to a diesel bus are reported in various studies as 86% [28], 96% [29] and 84% [30]. A Swiss study found PM emissions from natural gas fuelled heavy goods vehicles to be 75% lower than the respective value for diesel-powered vehicles [7].

Some studies have found similar or higher levels of PM and high PM chemical toxicity in CNG buses compared to diesel buses; however, a review of a number of different studies reported that the most likely source of these particles is from inefficient exhaust after-treatment or engine lubricating oil, rather than from the actual methane fuel [27]. It is therefore important that CNG engines have good oil control and suitable exhaust after-treatment in order to minimise PM emissions.

Carbon monoxide (CO)

Emissions of CO from diesel engines are normally low, but can be a problem in old petrol vehicles without catalysts [27]. Natural gas engines fitted with catalysts have low CO emissions, with no significant difference reported between CNG and diesel engines [27,29]. A separate study carried out in India reported reductions in CO emissions of 56% in a CNG compared to a diesel bus [28].

Sulphur dioxide (SO_2)

CNG is almost free of sulphur [31]. Monitoring of air quality in Delhi following the conversion of almost half of the vehicles to CNG showed a reduction in levels of SO_2 of 22% [28].

Hydrocarbons (HC)

Legislation in the US differentiates between methane and non-methane hydrocarbons (NMHCs), and regulates NMHCs [27]. This is based on the fact that methane is neither toxic nor reactive, i.e. it is not harmful to human health. However, it should be noted that methane is a significant greenhouse gas with a global warming potential of 21 [32].

In a natural gas engine, over 90% of the total hydrocarbon (THC) emissions are typically methane, with only a small amount resulting from NMHCs [27]. Of the NMHCs, the main aldehyde produced is formaldehyde, but these emissions can be significantly reduced by the use of a catalyst. The tendency of natural gas to form polycyclic aromatic hydrocarbons compounds (PAHs) is small, and PAHs in natural gas exhaust generally originate from the engine lubricating oil; good oil control is therefore recommended in CNG engines [27].

Petrol vehicles without catalysts are a major source of hydrocarbons, particularly two- and three-wheelers with two-stroke engines [27]. A Swiss study found natural gas vehicles to have 73% lower NMHC than petrol-fuelled passenger cars [7]. With regard to diesel vehicles, an Italian study found the emissions from CNG buses to be 50 times lower for carcinogenic PAHs, and 20 times lower for formaldehyde, than from a diesel bus [29]. The typical hydrocarbon emission reduction in CNG bus compared to a diesel bus is quoted as 55% [28] and 67% [29].

Barriers

Non-technological barriers, gaps and challenges retarding the widespread use of biomethane and CNG in vehicles in Europe [33, 34]:

- Unfavourable and/or inadequate policies, standards and regulations in most European countries.
- Biomethane use for electricity generation is in most countries incentivised through the issue of green certificates and other tradable allowances, while no direct incentives exist for biomethane used as a transport fuel (with the exception of EU targets for biofuels and national laws ratifying these).

- Other challenges to the market expansion of natural gas and biomethane are the chicken-and-egg problem of vehicle adoption and infrastructure build-up (the limited number of filling stations), and there are also issues with fleet operator attitudes, general unawareness and preferences towards alternatively fuelled vehicles.
- Political barriers, convincing critics about the synergistic market effect of a mixed supply of natural gas and biomethane. Especially larger fleets along with heavy vehicles and municipal services and utilities should be addressed in the near future as there is a great and unused potential.
- The current UK gas vehicle market suffers from poor availability of both refuelling infrastructure and vehicles, and so provides a limited market to potential fuel suppliers.
- The additional capital costs of gas vehicles outweigh the potential fuel costs savings in most cases, and so it is viewed as an uneconomic fuel by vehicle operators.
- The lack of experience of gas vehicles and the limited fleet sizes in the UK has resulted in concerns about reliability of gas vehicles.

Biogas as a transport fuel in Northern Ireland

In 2011, the main sources of greenhouse gas emissions were agriculture (28.0 %), transport (21.0 %), energy supply (18.8 %), and the residential sector (15.7 %). Transport emissions have increased by 25.1 % since the base year although, since a peak in 2007, there has been a reduction of 8.8 % over the last four reported years. The other sectors, with the exception of land use, land use change and forestry (which accounts for less than 1 % of emissions) have seen a decreasing trend in emissions since the base year [35]. There are 1,060,328 vehicles in NI (Table 9) and we imported 764,756 tonnes of diesel and petrol (Table 10).

In 2010, Northern Ireland (NI) emissions of carbon dioxide (CO_2) amounted to 14,657 kt, a decrease of 12 % on 1990 emissions of CO_2. This CO_2 emissions in 2010 represented 3.0 % of UK CO_2 emissions. Greenhouse gas emissions in the transport sector accounted for 3,331 kt CO_2 equivalent in 2010 [36]. From Tables 6, 7 and 8, it can be seen that using NG as a fuel for transport will reduce greenhouse gas emissions. At the moment in NI, there are not NG fuelling stations or NG vehicles, which show the huge potential for using biogas as a transport fuel.

Table 9 Vehicles currently licensed by body type in 2012 in NI [37]

Body type	2012	
	Number	%
Car	877,586	82.8
Taxi	610	0.1
Motorcycle	26,998	2.5
Tricycle	255	0.0
Light Goods Vehicle	97,087	9.2
Heavy Goods Vehicle	22,384	2.1
Bus/Coach	5,835	0.6
Agricultural Vehicle	23,169	2.2
Other	6,404	0.6
All body types	**1,060,328**	**100.0**

Table 10 Deliveries of petrol and diesel for use in NI: 2012 - 2013 [37]

	Tonnes	%	Kg CO_2/t of fuel consumed[38]
PETROL			
Super	61,322	*8.0*	*3,005.80*
Premium (95 Ron)	237,883	*31.1*	*3,005.80*
All unleaded petrol	**299,205**	***39.1***	
DIESEL			
ULSD	465,551	*60.9*	*3,100.10*
All Diesel	**465,551**	***60.9***	
All Petrol and Diesel	**764,756**	***100.0***	

Case Studies

European Case Study: Sweden, Linköping

The Linköping Biogas plant is located in the East of the country, where there is no gas grid. It has an annual treatment capacity of 100 000 tonnes of biomass, coming from animal manure and different food industries in the vicinity of city (which has 140 000 inhabitants). It produces 4.7 million m^3 of upgraded biogas (97% methane), used in 64 buses and a number of HDVs (trucks) and LDVs (private cars, taxis and distribution vehicles). The plant started production in 1997 and this year the first buses also started running on biogas. Since 2002, the urban transport fleet consists of only biogas buses, resulting in a CO_2 reduction of 9 000 t/yr. In addition to the slow filling station for buses, which are refuelled during the night, there are also 12 public biogas fast filling stations, some of which are supplied through a low pressure pipeline from the upgrading plant and some of which are supplied through a container system. Emission levels were lowered from Euro 1 to Euro 5 levels and greenhouse-gas emissions are now zero (on a lifecycle basis). Apart from the transportation aspects of the project, artificial fertiliser has been replaced by digestate from the biogas plant and an environmentally sound process is now available for the treatment of regional organic waste [39].

UK Cases Studies

Table 11 shows cases studies of companies using HGV and buses using biogas as a fuel.

Table 11 Cases Studies of HGV and public transport using biomethane as a fuel in the UK

Company	Vehicles	Project	Location	Key Findings
Coca-Cola [40]	14 of 26 tonne Iveco Stralis trucks. Fuel : Only Biomethane	The Coca-Cola Enterprises Ltd Biomethane vehicle trial	London	- NOx emissions reduced by 85.6% - PM emissions reduced by 97.1% - GHG emission savings of 50.3% - Preferred performance by the drivers - Total cost of ownership increased by 15.3%
Sainsbury's [41]	51 of Genesis Edge dual-fuel (Diesel- liquid biomethane (LBM))	Running on Rubbish Trial	Bristol	- Reduction of consumption of diesel and carbon emissions - Each vehicle saves around 41 tonnes of CO_2 emissions per year
Tesco [42]	35 Mercedes dual-fuel (Diesel-LBM)	N/A	Daventry	- CO_2 emissions reduced by 15% - NOx and PM emissions reduced by 90%
DHL [43]	101 of dual-fuel (Diesel- LNG)	N/A	Bawtry	- Reduction of diesel consumption - Reduction of CO_2 emissions by 10-14%
Anglian Bus [44]	13 MAN Ecocity buses, Fuel: only biomethane		Beccles	- 96% less emissions - Cleaner air

References

1. Goulding D, Power N. Which is the preferable biogas utilisation technology for anaerobic digestion of agricultural crops in Ireland: Biogas to CHP or biomethane as a transport fuel? *Renew Energy*. 2013;53:121–131. doi:10.1016/j.renene.2012.11.001.

2. European Biofuels Technology Platform. Biofuels and Sustainability Issues. Available at: http://www.biofuelstp.eu/sustainability.html.

3. European Biofuels Technology Platform. Biofuels and Sustainability Issues.

4. Biofuel Policy Watch. The Controversial Proposed Revision to the EU Renewable Energy Directive. Available at: http://biofuelpolicywatch.wordpress.com/2013/01/22/the-controversial-proposed-revision-to-the-eu-renewable-energy-directive/.

5. Natural and Biogas Vehicle Association. WORLDWIDE NGV STATISTICS. Available at: WORLDWIDE NGV STATISTICS.

6. Bioenergy IEA. UPGRADING AND UTILISATION BIOGAS UPGRADING AND UTILISATION Table of Contents.

7. Monson KD, Esteves AJ, Guwy AJ, Dinsdale RM. *Anaerobic Digestion of Biodegradable Municipal Wastes: A Review*.; 2007:368. Available at: http://www.walesadcentre.org.uk/Controls/Document/Docs/Anaerobic Digestion of BMW _compressed_ - A Review _for print_.pdf.

8. Ontario Ministry of Agriculture and Food. Vehicle Conversion to Natural Gas or Biogas. Available at: http://www.omafra.gov.on.ca/english/engineer/facts/12-043.htm.

9. Ontario Ministry of Agriculture and Food. Vehicle Conversion to Natural Gas or Biogas.

10. Nijboer M. *The Contribution of Natural Gas Vehicles to Sustainable Transport*.; 2010. Available at: http://www.iea.org/publications/freepublications/publication/natural_gas_vehicles.pdf.

11. Åhman M. Biomethane in the transport sector—An appraisal of the forgotten option. *Energy Policy*. 2010;38(1):208–217. doi:10.1016/j.enpol.2009.09.007.

12. Persson M, Wellinger A, Braun R, et al. *Biogas Upgrading to Vehicle Fuel Standards and Grid Injection*.; 2006. Available at: http://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/upgrading_report_final.pdf.

13. The Wales Centre of Excellence for Anaerobic Digestion. Gas Utilisation. Available at: http://www.walesadcentre.org.uk/Technologies/GasUtilisation.aspx.

14. GasHighWay. *GasHighWay - Route to Green Transportation*.; 2012:40. Available at: http://www.gashighway.net/GetItem.asp?item=digistorefile;338235;1197&params=open;gallery.

15. CNG Filling Stations Europe. 2013. Available at: http://cng-stations.bplaced.net/Europa.en.htm.

16. Bord Gáis. *Compressed Natural Gas : A viable transport fuel*.; 2010. Available at: http://www.engineersireland.ie/public/sponsor-bordgais-cng.pdf.

17. Bonsall B. Developing a BioCNG Transport Fuel Industry in Ireland TCBB Introduction. In: *Biomethane for Transport, IRBEA*.; 2013. Available at: http://www.irbea.ie/images/AD/bart bonsall tcbb irbea biomethane.pdf.

18. Murphy JD, Power NM. An argument for using biomethane generated from grass as a biofuel in Ireland. *Biomass and Bioenergy*. 2009;33(3):504–512. doi:10.1016/j.biombioe.2008.08.018.

19. Smyth BM, Murphy JD, O'Brien CM. What is the energy balance of grass biomethane in Ireland and other temperate northern European climates? *Renew Sustain Energy Rev*. 2009;13(9):2349–2360. doi:10.1016/j.rser.2009.04.003.

20. Smyth BM, Ó Gallachóir BP, Korres NE, Murphy JD. Can we meet targets for biofuels and renewable energy in transport given the constraints imposed by policy in agriculture and energy? *J Clean Prod*. 2010;18(16-17):1671–1685. doi:10.1016/j.jclepro.2010.06.027.

21. Howley M, Dennehy E, Gallachóir BÓ, Cammish N, Cunningham S, Mcdonnell D. Energy in Transport. 2009;(October). Available at: http://www.sei.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_in_Transport/Energy_In_Transport_2009_Report.pdf.

22. Brightman T, Matthews C. *Biomethane for Transport - HGV cost modelling*.; 2011.

23. Biaggini G, Knecht W. The Advanced Iveco Cursor 10 Heavy Duty Truck Diesel Engine. *SAE*. 2000.

24. IVECO S.p.A. NEW ECOSTRALIS . THE PERFECT FORMULA THAT COMBI NES ECONOMY AND ECOLOGY. Available at: http://www.iveco-stralis.eu/ECOSTRALIS_CAT_ING.pdf.

25. Papagiannakis RG, Rakopoulos CD, Hountalas DT, Rakopoulos DC. Emission characteristics of high speed, dual fuel, compression ignition engine operating in a wide range of natural gas/diesel fuel proportions. *Fuel*. 2010;89(7):1397–1406. doi:10.1016/j.fuel.2009.11.001.

26. Atkinson C, Traver M, Tennant C, Atkinson R, Clark N. Exhaust Emissions and Combustion Stability in a Bi-Fuel Spark Ignition Engine. *SAE Tech Pap*. 1995;(950468). Available at: http://papers.sae.org/950468/.

27. Nylund N-O, Erkkilä K, Lappi M, Ikonen M. *Transit bus emission study: comparison of emissions from diesel and natural gas buses, VTT Processes*.; 2004. Available at: http://www.madegascar.eu/Downloads.265.0.html.

28. Goyal P. Present scenario of air quality in Delhi: a case study of CNG implementation. *Atmos Environ*. 2003;37(38):5423–5431. doi:10.1016/j.atmosenv.2003.09.005.

29. Turrio-Baldassarri L, Battistelli CL, Conti L, et al. Evaluation of emission toxicity of urban bus engines: compressed natural gas and comparison with liquid fuels. *Sci Total Environ*. 2006;355(1-3):64–77. doi:10.1016/j.scitotenv.2005.02.037.

30. Melendez M, Taylor J, Zuboy J, Smith D. *Emission Testing of Washington Metropolitan Area Transit Authority (WMATA) Natural Gas and Diesel Transit Buses Emission Testing of Washington Metropolitan Area Transit Authority (WMATA) Natural Gas and Diesel Transit Buses*.; 2005. Available at: http://www.nrel.gov/docs/fy06osti/36355.pdf.

31. Krzyzanowski M, Kuna-Dibbert B, Schneider J. *Health effects of transport-related air pollution*. Copenhagen: World Health Organisation (WHO); 2005. Available at: file:///L:/Applied Research/NON-EU PROJECTS/DO-BioEnergy/Project Implementation/Working groups/Uses/Kryzanowski health effects of transport related air pollution.pdf.

32. Forster P, Ramaswamy V, Artaxo P, et al. *Changes in Atmospheric Constituents and in Radiative Forcing. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, USA; 2007.

33. GasHighWay. Available at: http://www.gashighway.net/default.asp?SivuID=26094.

34. NSCA. *Biogas as a road transport fuel*.; 2006. Available at: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&cad=rja&ved=0CHoQFjAJ&url=http%3A%2F%2Fwww.cleanvehicle.eu%2Ffileadmin%2Fdownloads%2FUK%2Fnsca_biogas_as_a_road_transport__084926300_1011_24042007.pdf&ei=jtrVUtGzBISM7AaQ-IGwAQ&usg=AFQjCNGVMHc-08dPePhDLngle_f9Aerprg&sig2=4m2BlKHHAvbpA1rav1fmwQ&bvm=bv.59378465,d.ZGU.

35. Department of Environment. *NORTHERN IRELAND GREENHOUSE GAS INVENTORY , 1990 - 2011*.; 2013:1–8. Available at: http://www.doeni.gov.uk/ghg-inventory-statistical-bulletin-2011.pdf.

36. Gibson D. *Northern Ireland Environmental Statistics Report January 2013. Theme : Agriculture and Environment*.; 2013:116. Available at: http://www.doeni.gov.uk/ni-environmental-statistics-report-2013.pdf.

37. Northern Ireland Statistics and Research Agency. *Northern Ireland Transport Statistics 2012-13*.; 2012:95. Available at: http://www.drdni.gov.uk/ni_transport_statistics_annual_2012-13.pdf.

38. Carbon Trust. *Conversion Factors. Energu and carbon convesions 2013 update*.; 2013:171. doi:10.1016/B978-0-12-401720-7.00015-0.

39. Nijboer M. *The Contribution of Natural Gas Vehicles to Sustainable Transport*.; 2010.

40. Carrol S. *The Coca-Cola Enterprises Biomethane Trial Report*.; 2012. Available at: hhttp://www.cenex.co.uk/LinkClick.aspx?fileticket=wzFSJX8rAGQ%3D&tabid=916.

41. J Sainsbury plc. Sainsbury's takes to the road to drive carbon reductions. Available at: http://www.j-sainsbury.co.uk/media/latest-stories/2013/20130530-sainsburys-takes-to-the-road-to-drive-carbon-reductions/.

42. Focus.com. Tesco fuels food deliveries with green Bio-LNG from Gasrec. 2013. Available at: http://www.renewableenergyfocus.com/view/32110/tesco-fuels-food-deliveries-with-green-bio-lng-from-gasrec/.

43. EdieEnergy. DHL expands duel fuel fleet to cut CO2 emissions. 2013. Available at: http://www.edie.net/news/6/DHL-expands-duel-fuel-fleet-to-cut-CO2-emissions/.

44. Anglian Bus. Available at: http://www.anglianbus.co.uk/about-us/overview/.

Biogas in industry and commerce

In 2011, the business sector in N Ireland was responsible for 11.5% of total GHG emissions, and combustion emissions from the manufacturing industry and construction accounted for 14% N Ireland's total carbon dioxide emissions in the same year (Aether Ricardo-AEA, 2013).

Emissions from business can be split into those from 'industry' and those from 'commerce'. The estimates of final energy demand in N Ireland industry and commerce and the related GHG emissions are given in Table 1 (Ricardo-AEA, 2013a).

Table 1: Final energy demand and energy-related GHG emissions in N Ireland industry and commerce in 2010 (Ricardo-AEA, 2013a)

	Energy demand		GHGs	
	GWh	%	ktCOte	%
Industry				
Electricity	2.2	25.6	1125	37
Fossil fuel	6.1	74.5	1885	63
Total	8.6	100	3011	100
Commerce				
Electricity	2.07	65.9	1061	80
Fossil fuel	1.07	34.1	264	20
Total	3.14	100	1325	100

The industry sub-sectors that make a significant contribution to energy consumption are chemicals and food, drink and tobacco (Ricardo-AEA, 2013b).

Of total fossil fuel use for heating in N Ireland, industry accounts for 28% and is the second largest sector after residential (62%); commerce is responsible for a further 5% (Ricardo-AEA, 2013a).

Oil and coal fired boilers currently account for 59% of heat in industry; such boilers are considerably less efficient than modern gas-fired condensing boilers (at 89%/83% net compared to 107% net) (Ricardo-AEA, 2013b).

Emissions from business in N Ireland decreased by an estimated 16% between 1990 and 2011, reflecting the impact of the growth of the gas network and fuel switching from oil- and coal-fired boilers to gas (Aether Ricardo-AEA, 2013).

As the gas grid is extended to the west of N Ireland, it is expected that more industries will switch to natural gas, improving energy efficiency and reducing greenhouse gas emissions (Ricardo-AEA, 2013b). If biomethane were used, a greater reduction in greenhouse gas emissions would result, along with a decrease in import dependency.

References

Aether Ricardo-AEA (2013). Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2011. Department of Energy and Climate Change, The Scottish Government, The Welsh Government, The Northern Ireland Department of the Environment.

Ricardo-AEA (2013a). Envisioning the Future Considering Energy in Northern Ireland to 2050 Main Report – Final Version. Department of Enterprise, Trade and Investment (DETI). Available at: http://www.detini.gov.uk/envisioning-the-future-2.

Ricardo-AEA (2013b). Envisioning the Future Considering Energy in Northern Ireland to 2050 Sector Annexes – Final Version. Department of Enterprise, Trade and Investment (DETI). Available at: http://www.detini.gov.uk/envisioning-the-future-2.