An introduction to the production of biomethane gas and injection to the national grid
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1 Introduction

The gap in organic waste treatment capacity in the West Midlands is predicted to reach 1.3 million tonnes in 2021. Each year 789,460 tonnes of organic municipal solid waste (MSW) and commercial and industrial (C&I) waste are currently disposed of to landfill. One means of diverting this organic waste away from landfill could be treatment via anaerobic digestion (AD) with the production of biogas which can be upgraded to biomethane and injected into the gas grid to produce renewable energy.

AD is a proven waste treatment technology with the added benefit of the production of renewable energy. It is widely used in both developed and developing countries. In England the water industry has a well-established system of AD facilities treating 66% of sewage sludge. However, in the treatment of municipal and agricultural wastes AD is still relatively rare in the UK but is much more widespread in continental Europe. The economic case for AD is changing as a result of increasing Landfill Tax, lower gate fees, the eligibility of electricity produced from AD for double Renewable Obligation Certificates (ROCs) and the support for injection of biomethane into the gas grid via the Renewable Heat Incentive (RHI) announced in March 2011 and to be launched in July 2011.

A wide range of feedstocks can be treated via AD including organic waste arising from households, C&I premises, farms, and sewage sludge. AD can also produce biogas from energy crops such as maize, grass, whole crop silage and root crops. Ensuring a sufficient and steady supply of feedstock is essential to the effective operation of an AD facility.

AD plants can benefit from economies of scale. However, capital and operating cost is not only dependent on the tonnage of feedstock that is treated but also on the type of feedstocks which facilities are designed to treat.

One of the advantages of AD over other biodegradable waste treatment options, such as composting and thermophilic aerobic digestion, is the production of biogas, which is a primary mixture of methane and carbon dioxide. In order to produce biomethane from the biogas it must first be cooled to condense the water vapour. Subsequent treatment of the biogas will be dependent upon the end use of the gas and the required quality. Biogas upgrading can be achieved by a number of systems including: absorption; pressure swing adsorption; membrane separation and cryogenic separation.

Once impurities are removed, biomethane must be enriched in order to reach the required calorific value equal to natural gas (roughly 11.3 kWh/m$^3$) as required by the Gas (Calculation of Thermal Energy) Regulations 1996. It is usually blended with gas with a higher energy content than natural gas such as propane.

The capital expenditure required for biogas upgrading equipment increases with throughput but there are economies of scale and the capex required per
unit of gas processed falls with increased throughput. It is estimated that for most European facilities capex for the upgrading technology is in the range of £0.65 - £0.80 per cubic metre of biogas upgraded.

The cost of connection to the grid is site specific but estimated to be in the region of £750,000 which is often seen as prohibitively expensive. High costs are also associated with the level of monitoring required to determine the quality and quantity of biomethane that is injected. There is currently a process of consultation underway with the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) to have more appropriate regulation for AD and biomethane injection. It is hoped that this will significantly reduce the cost of grid injection to around £400,000 including installation and monitoring.

The production of biomethane as a result of AD can be considered as relatively consistent in comparison with other renewable energy sources such as wind generation as a result of the continuous operation of an AD plant that receives a consistent supply of feedstock which is then converted to biogas over a number of weeks in a managed process. Production of biomethane helps to reduce variability in supply as it can be stored off site in the grid, both in the pipe network and in storage facilities.

When comparing uses of biogas it is important to quantify the benefits in terms of saved emissions to the environment. When comparing gas injection, electricity production and transport fuel, two variables are particularly important:

1. The efficiency with which biogas is converted to its product (either biomethane, electricity or transport fuel)

2. The extent of emissions which are avoided by using the biogas as a product

The Carbon Trust found that when accounting for both the efficiency of biogas upgrading and the standard carbon displacement figures, using biomethane as a transport fuel provided the best saving for 2010 with electricity being the next best option. The savings for gas to grid are lower – this is because the natural gas it replaces is a relatively low carbon fossil fuel, and this technology has a high parasitic load. In 2020 the Carbon Trust predict a reduction in the savings associated with electricity production, as a lower carbon displacement value is used which represents less emissions from displaced electricity as more renewables are used. Therefore looking to the future, biomethane to gas grid may provide a good choice of technology from a carbon savings point of view.
2 Anaerobic digestion and biogas production

2.1 Anaerobic digestion process
Anaerobic digestion (AD) is the breakdown of organic matter by methanogenic bacteria in controlled, oxygen free conditions to produce:

1. Biogas (methane, carbon dioxide and small quantities of other compounds)

2. Digestate which is usually separated into:
   a. A solid fibrous component after dewatering
   b. A nutrient rich liquid fraction

In contrast to composting, AD is a bacterial process and does not involve other organisms such as fungi and micro-fauna. A wide variety of bacteria are involved in AD processes that thrive under neutral pH conditions of between 6.4 and 8.2. If the pH conditions are outside this range it can cause the AD process and rate of biogas production to slow down or stop.

Whilst a wide range of AD processes and technologies are available, a typical process will involve the wetting, pulping and heating of the input feedstocks, followed by the extraction, cleaning and storage of the biogas, and dewatering of the digestate into separate fractions of solid and liquid. The process temperature is variable and at temperatures between 33°C and 37°C the process is known as mesophilic, in contrast to thermophilic conditions of between 55°C and 60°C. An AD process does not produce heat intrinsically and so the optimum temperature range is maintained by the application of an external heat source.

A typical AD process involves wetting, pulping and heating of feedstocks, followed by extraction, cleaning and storage of biogas, and dewatering digestate into solid and liquid fractions

The bacteria involved in AD rely on the provision of nitrogen as a nutrient for growth. Optimum methane production is dependent upon a carbon to nitrogen (C:N) ratio of between 20:1 and 30:1. A C:N ratio outside this range can cause the AD process and rate of biogas production to slow down or stop. Optimum C:N ratios can be achieved by mixing feedstocks that are high in nitrogen such as food waste and animal manure, with those that are high in carbon including paper and cardboard.

The organic loading rate (OLR) is a measurement of the biological conversion capacity of an AD process. It is especially important in continuous systems when feeding the digester in excess of its OLR will result in a lower yield of biogas due to the accumulation of inhibiting substances such as volatile fatty acids in the digester slurry.

Effective degradation of the organic material is reliant upon a sufficient retention or residence time in the digestion process. Residence time is heavily
dependent upon the feedstock composition, OLR, and process temperature and type. Physical mixing of the feedstock within the digester is essential for a number of reasons. Firstly to improve contact between the bacteria and the feedstock substrate but also to improve heat transfer and provide a uniform temperature, and to prevent the formation of dead zones, scum layers and sediment layers which reduce the efficiency of the process.

In the treatment of residual municipal solid waste (MSW) AD may be included as part of a larger treatment process known as mechanical and biological treatment (MBT). MBT is the generic term for an integration of several processes commonly found in other waste management technologies such as materials recovery facilities (MRFs), sorting and composting or AD plant involving both mechanical and biological treatment processes. MBT may produce compost like output (CLO) which is a stabilised output which may be used on land although it has the potential to contain contaminants arising from the mixed residual waste streams. In addition refuse derived fuel (RDF) or solid recovered fuel (SRF) may also be generated. This is the highly calorific, usually oversize, output that has not been digested and can be used in energy recovery.

2.2 Feedstocks and security of supply

A wide range of feedstocks can be treated via AD including but not limited to:

- Organic household waste
- Organic commercial and industrial wastes
- Catering waste
- Animal by-products
- Organic farm wastes
- Sewage sludge
- Green garden wastes - although those with a high lignocellulosic content do not readily degrade under anaerobic conditions
- Energy crops such as maize, silage and root crops

Feedstocks for AD are usually characterised according to the following parameters:

1. Total solids (TS) – The amount of dry solids (organic and nonorganic) in a material.
2. Volatile solids (VS) – The organic, carbon-containing fraction of the TS.

The suitability of different technologies is dependent upon the input feedstock characteristics. In general, the higher the solids content and the more non-degradable components present, the more complex the AD process technology must be. Homogenous, liquid feedstocks with no contraries such as slurry, wastewater and energy crops are relatively easy to digest and thus simpler AD technology is required. These feedstocks can usually be fed
directly into the digester and do not need front end preparation to separate contraries from the feedstock.

Feedstocks requiring more complex AD technology are source separated food and garden waste or organics separated from municipal solid waste. This includes unsuitable materials (inerts, metals, plastics etc.) which must be removed by the process technology.

The type of digestion will be dependent upon the dry matter content of the input material. Wet digestion is used where the dry matter content is less than 15% and is appropriate when the input feedstock is food waste only or animal manure and slurry. Semi-dry digestion is used where the dry matter content of the input material is between 15% and 20% and could be used to treat mixed feedstocks such as food and garden waste. Finally, dry digestion is suitable for input material with a dry matter content of greater than 20% such as a feedstock with a high proportion of garden waste or dry crop residue.

Domestic biodegradable waste, typically from kitchen and garden, but also sometimes including card and non-recyclable paper has the potential to be a valuable feedstock to an AD facility. Unlike C&I, waste treatment contracts are often let for long periods of ten to twenty five years and they may also have options for extensions. This waste stream can therefore provide the foundation on which to develop and finance an AD plant. Subject to being allowed within the contract with the local authority, this feedstock can then be supplemented with compatible C&I waste which may attract a higher gate fee but would typically be subject to a much shorter contract period thus being less secure over time.

Domestic biodegradable waste has the potential to be a valuable feedstock for AD. Waste treatment contracts are often let for 10 - 25 years and this waste stream can therefore provide the foundation on which to develop and finance an AD plant.

Furthermore, in the UK the two waste streams have different regulatory drivers. Domestic waste is subject to the Landfill Directive which requires the diversion of biodegradable municipal waste (BMW) from landfill. The Landfill Allowance Trading Scheme (LATS) was set up in England to encourage local authorities to comply with this requirement. Under LATS if a local authority has BMW to send to landfill in excess of their allowances, they must purchase allowances from local authorities which have an excess. It should be noted that in Wales, allowances cannot be traded. This system was created to provide an incentive for local authorities to introduce systems and infrastructure for the separation at source and treatment of BMW in a way which diverts it from landfill. The diversion of BMW from landfill also reduces the tonnage of waste which attracts the combined gate fee and landfill tax.

For C&I waste the only incentive is the avoidance of the gate fee and landfill tax as LATS does not apply to this waste stream. This is one of the reasons why separation at source and diversion of C&I wastes from landfill has lagged behind municipal waste. In addition, it is likely that large producers of organic
waste may have secured markets for their ‘waste’ products. In a recent study by WRAP and ORA regarding organic waste in the West Midlands, waste from a chocolate producer was found to have revenue of £38 per tonne due to its value as animal feed. If this is the case it is unlikely that the waste producer will consider alternate disposal routes that do not attract the benefits of revenue.

In contrast to the situation often found in continental Europe, in the UK C&I waste and domestic waste are not normally collected in the same waste collection round. Therefore these streams often have very different logistics and commercial considerations when it comes to determining how they might be collected and delivered to an AD facility.

Farm based AD facilities treating agricultural wastes may require supplementary feedstocks during the summer months when livestock are outdoors and therefore manure and slurry is not available and/or increased storage capacity to supply feedstock over the summer months. Farmers may be unlikely to consider municipal sources of organic waste due to associated requirements for more complex planning and licensing, and issues surrounding use of the digestate. One option is to use energy crops although the economic and carbon cost of producing energy crops often limits their use in comparison to by product crop materials. In addition there are concerns over using valuable and often limited areas of land to produce energy crops when this could be better utilised to produce food crops. Alternative supplementary feedstocks could include:

1. Break crops (required in arable rotation farming to maintain soil and plant health) such as maize and beet silage

2. Cover crops including green manure crops (good practice for soil management and reduction of diffuse water pollution)

There is also the potential to consider replacing the use of land for the production of arable crops for intensive livestock production in favour of energy crops for environmental benefits of reducing livestock product consumption.

Operators of farm-based AD may be unlikely to consider municipal waste feedstocks due to more complex planning and licensing requirements, and issues around use of digestate.

2.3 Variability of biogas production

Variability in the supply of energy is sometimes quoted as a disadvantage of renewable sources. Indeed, in the same manner as other technologies, AD has its own natural cycles of production. The primary effects seen in AD are those which are properties of the feedstock. Feedstocks can vary in their abundance through the year due to different anthropogenic and climatic effects. For example food waste arisings may not be considered to vary considerably through the year, but garden waste arisings generally peak twice; once in spring and once in late summer. Depending on the species,
energy crops are highly seasonal in their production. However they are usually stored which smoothes out the supply.

Inherently, AD is less variable on short timescales than technologies such as wind as the feedstock supply is more consistent and the biogas production process is actively managed. This helps to produce a smooth biogas production curve. Production of a gas helps to reduce variability in supply as it can be stored off site in the grid, both in the pipe network and in storage facilities. Gas storage within the gas grid is explained in Section 4.

**AD is less variable on short timescales than technologies such as wind as the feedstock supply is more consistent and the biogas production process is actively managed.**

### 2.4 Products of digestion and quality standards

#### 2.4.1 Biogas

One of the advantages of AD over other biodegradable waste treatment options is production of biogas which is a primary mixture of 40-70% methane (CH₄) and 30-60% carbon dioxide (CO₂), along with small quantities of other gases including hydrogen (H₂), hydrogen sulphide (H₂S), ammonia (NH₃), and carbon monoxide (CO). In addition, fresh biogas is saturated with water vapour and may also contain particulates and organic silicon compounds (siloxanes). The proportion of each component is dependent upon the feedstock and process type.

Before the biogas can be utilised it must be cooled to condense the water vapour. Additional treatment of the biogas will be dependent upon the end use of the gas and therefore the required gas quality.

**Gas Safety (Management) Regulations**

The Gas Safety (Management) Regulations 1996 (GSMR) apply to the conveyance of natural gas through pipes to domestic and other consumers and cover four main areas:

1. Safe management of gas flow through a network, particularly those parts supplying domestic consumers, and a duty to minimise the risk of a gas supply emergency
2. Arrangements for dealing with supply emergencies
3. Arrangements for dealing with reported gas escapes and gas incidents
4. Gas composition

The content and characteristics of gas are defined in Schedule 3 of the Regulations which state that under normal conditions the values in Table 1 apply.
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<table>
<thead>
<tr>
<th>Content or characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen sulphide content</td>
<td>≤5 mg/m³</td>
</tr>
<tr>
<td>Total sulphur content (including H₂S)</td>
<td>≤50 mg/m³</td>
</tr>
<tr>
<td>Hydrogen content</td>
<td>≤0.1% (molar)</td>
</tr>
<tr>
<td>Oxygen content</td>
<td>≤0.2% (molar)</td>
</tr>
<tr>
<td>Impurities</td>
<td>shall not contain solid or liquid material which may interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate</td>
</tr>
<tr>
<td>Hydrocarbon dew point and water dew point</td>
<td>shall be at such levels that they do not interfere with the integrity or operation of pipes or any gas appliance (within the meaning of regulation 2(1) of the 1994 Regulations) which a consumer could reasonably be expected to operate</td>
</tr>
<tr>
<td>WN (Wobbe Number)</td>
<td>(i) ≤51.41 MJ/m³ and (ii) ≥47.20 MJ/m³</td>
</tr>
<tr>
<td>ICF (Incomplete Combustion Factor)</td>
<td>≤0.48</td>
</tr>
<tr>
<td>SI (Soot Index)</td>
<td>≤0.60</td>
</tr>
</tbody>
</table>

Table 1: UK gas quality standards

In addition the regulations state that the gas shall have been treated with a suitable stenching agent to ensure that it has a distinctive and characteristic odour which shall remain as such when the gas is mixed with gas which has not been so treated. The gas shall be at a suitable pressure to ensure the safe operation of any gas appliance which a consumer could reasonably be expected to operate.

Whilst it may be considered that some of the standards shown in Table 1 are too costly and carbon intensive to achieve for biomethane, it should be noted that Regulation 11 of the GSMR enables the Health and Safety Executive (HSE) to exempt duty holders from any of the requirements or prohibitions imposed by the regulations if it is satisfied that the health and safety of persons likely to be affected by the exemption will not be prejudiced as a consequence. For example, according to a report by the HSE¹ whilst the biomethane produced at the Didcot sewage treatment works may have an oxygen content of up to 2% compared with the limit of 0.2% set by the GSMR, the HSE is satisfied that there is no increased risk to either gas consumers or the public. As such the HSE issued a GSMR exemption to Scotia Gas Networks to allow biomethane to be conveyed in a limited area around the Didcot biomethane plant. The report confirms that this is the third biomethane to grid facility in Great Britain to be granted a GSMR exemption.

The injection of biomethane to the gas grid is more widely practised in various EU countries including Germany, Luxembourg, The Netherlands, Sweden and Austria. It is interesting to compare the standards for biomethane quality in the UK with these countries as shown in Table 2.

Table 2: Comparison of gas quality standards in selected EU countries

<table>
<thead>
<tr>
<th>Content or characteristic</th>
<th>UK</th>
<th>Germany</th>
<th>Netherlands</th>
<th>Sweden Biomethane A</th>
<th>Sweden Biomethane B</th>
<th>Austria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen sulphide content (mg/m³)</td>
<td>≤5</td>
<td>≤5</td>
<td>≤5</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Total sulphur content including H₂S (mg/m³)</td>
<td>≤50</td>
<td>&lt;30</td>
<td>45</td>
<td>&lt;23</td>
<td>&lt;23</td>
<td>10</td>
</tr>
<tr>
<td>Hydrogen content (%)</td>
<td>≤0.1 (molar)</td>
<td>&lt;5</td>
<td>12</td>
<td>n/a</td>
<td>n/a</td>
<td>&lt;4</td>
</tr>
<tr>
<td>Oxygen content (%)</td>
<td>≤0.2 (molar)</td>
<td>&lt;3</td>
<td>0.5 (3 in dry grid)</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Wobbe Number (MJ/m³)</td>
<td>≤51.41 and ≥47.20</td>
<td>37.80 - 56.52</td>
<td>43.46 - 44.41</td>
<td>47.4 - 46.4</td>
<td>43.9 - 47.3</td>
<td>47.88 - 56.52</td>
</tr>
<tr>
<td>ICF (Incomplete Combustion Factor)</td>
<td>≤0.48</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>SI (Soot Index)</td>
<td>≤0.60</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

It is evident that some variation between the defined standards exists, with the UK having the lowest limits of those countries compared for hydrogen and oxygen content.

The UK has more stringent gas quality standards that some other EU countries where biomethane injection to the grid is well developed.

Biomethane Quality Protocol

The Environment Agency (EA) is currently looking at the standards which biomethane from AD must achieve in order to be considered non-waste and therefore encourage its use as electricity and transport fuel and for injection to the grid. The solid and liquid outputs from AD are already covered by a Quality Protocol. However, the gas produced from the treatment of waste by AD is not. The proposed Quality Protocol will provide regulatory clarity about the point at which biomethane is no longer considered as a waste and help establish a consistent set of standards required in order to facilitate direct injection to the grid and reduce costs.

To provide interim guidance until the Quality Protocol is published the EA have issued a draft position statement regarding their regulatory position in relation to biomethane from AD. The EA state that while work is in progress regarding the Quality Protocol their position is that biomethane from AD remains a waste until it has been put to use. Biomethane produced for injection into the gas grid must meet the additional compositional requirements set out in Table 3.

Table 3: EA requirement for biomethane quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total halogens, expressed as chlorine</td>
<td>1.5 mg/m³</td>
</tr>
<tr>
<td>Arsenic, antimony, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, thallium, vanadium, zinc</td>
<td>Below limits of detection to achieve the following performance criteria :</td>
</tr>
<tr>
<td></td>
<td>1. Limit of quantification- 1ppm for any individual metal</td>
</tr>
<tr>
<td></td>
<td>2. Precision of 10%</td>
</tr>
<tr>
<td></td>
<td>3. Maximum bias of 10%</td>
</tr>
<tr>
<td></td>
<td>(UKAS accredited laboratory using an appropriate validated methodology)</td>
</tr>
</tbody>
</table>
Biomethane producers must ensure that suitable and sufficient tests are carried out and records kept in order to demonstrate that the specified gas quality requirements are complied with at all times.

### 2.4.2 Digestate and liquor

Digestate in its raw slurry form is rarely used and it is normally dewatered to separate it into two fractions: liquor and fibre.

The AD liquor is usually partly recirculated as a process feed water. It is high in nutrients and may also be suitable for use as a liquid fertiliser. It has the benefit that it can be applied at all times of the crop cycle subject to control of the application rate to protect surface and groundwater.

Digestate fibre contains a relatively low level of plant nutrients but provides a good source of nitrogen, phosphorus and micro-nutrients including magnesium and iron. It is suitable for use as a peat-free soil conditioner or low grade fertiliser. Further processing of the fibre via aerobic composting can produce a high quality stable compost product.

#### PAS 110

The Publicly Available Specification (PAS) 110 covers whole digestate, separated liquor and separated fibre derived from the AD of source-segregated biodegradable materials. The purpose of the PAS is to remove a major barrier to the development of AD by encouraging markets for digested materials. It provides an industry specification against which producers can check that the digested materials are of consistent quality and fit for purpose. Along with other supply and demand market development measures, the PAS should encourage more sustainable practices in the management of biowastes.

The specification sets out the minimum quality required for whole digestate, separated liquor and separated fibre which may be used as a fertilizer or soil improver. Meeting its quality and other criteria enables the producer to demonstrate conformance to this PAS and therefore achieve the best market value for this product of digestion.

The specification follows a digestate production sequence, beginning with requirements for the input materials, through process management controls and monitoring, then to digestate sampling, testing, validation checks and information for end users. The PAS places requirements upon the producer to undertake Hazard Analysis and Critical Control Point (HACCP) planning and to implement and maintain a digestate Quality Management System (QMS).

#### Quality protocol for AD

The Quality Protocol sets out criteria for the production of quality outputs from AD of discarded material that is biodegradable and source segregated. Quality outputs from AD include:

1. Whole digestate
2. Separated fibre fraction
3. Separated liquor

If these criteria are met, the quality outputs will normally be regarded as having been fully recovered and cease to be waste (as defined in the Waste Framework Directive) when dispatched to the customer.

Producers and users are not obliged to comply with the Quality Protocol. However, if they do not, then quality outputs from AD will be considered to be waste and waste management controls will apply to their handling, transport and application.

The Quality Protocol has three main objectives:

1. To clarify the point at which waste management controls are no longer required
2. To provide users with confidence that the digestate they purchase complies with an approved standard
3. To protect human health and the environment by describing acceptable good practice for the use of quality digestate in agriculture, forestry and land restoration

When the AD process is part of an MBT facility treating mixed residual municipal solid waste the products of digestion will not meet the criteria defined in PAS110 and the Quality Protocol and as such it may be more difficult to secure an end market for the digestate or CLO produced.

2.5 Permitting of AD facilities

The Environmental Permitting Regulations (England and Wales) 2010 were introduced in April 2010 to replace the 2007 Regulations. There are two types of environmental permit and in addition certain activities may qualify for an exemption. Exemptions are for activities that don’t need a permit but most will still need to be registered with the Environment Agency. Standard permits are a set of fixed rules and charges for common activities where certain requirements must be met. Bespoke permits are written specifically for larger and more complex activities and the associated costs tend to be higher.

The standard permits that apply to AD are SR2010No15 “Anaerobic digestion facility including use of the resultant biogas”, SR2010No16 “On-farm anaerobic digestion facility including use of the resultant biogas” and SR2010No17 “Storage of digestate from anaerobic digestion plants”.

Standard permits can be applied for if the operation meets the following risk criteria and complies with the specific rules defined for each permitted activity:

- The activities shall not be within:
An introduction to the production of biomethane gas and injection to the national grid
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SR2010No15 AD facility including use of the resultant biogas
This standard permit allows an operator to operate an AD facility for the treatment of wastes (non-hazardous), with use of the biogas, in compression and spark ignition engines, with an aggregate rated thermal input of up to 3 megawatts. The rules also allow the use of standard commercial gas turbines, fuel cells or treatment followed by injection into the gas grid. The total quantity of waste that can be accepted at any site under these rules must not exceed 75,000 tonnes per year. Any wastes controlled by the Animal By-Products Regulations must be treated and handled in accordance with any requirements imposed by those regulations. The permitted activities must not be carried out within 250 metres of any off-site building used by the public, including dwelling houses.

This standard permit allows the following activities:

- Treatment of waste including shredding, sorting, screening, compaction, baling, mixing and maceration
- Digestion of wastes including pasteurisation and chemical addition
- Gas cleaning by biological or chemical scrubbing
- Gas storage and drying
- Treatment of digestate including screening to remove plastic residues, centrifuge or pressing, addition of thickening agents (polymers) or drying
- Composting and maturation of digestate
- The use of combustible gases produced as a by-product of the anaerobic digestion process as fuel
- Except for the auxiliary flare, the aggregate rated thermal input of all appliances used to burn biogas shall be less than 3 megawatts
- The maximum throughput of animal wastes shall be <10 tonnes per day

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2 European Site means candidate or Special Area of Conservation and proposed or Special Protection Area in England and Wales, within the meaning of Council Directives 79/409/EEC, 92/43/EEC and the Conservation (Natural Habitats &c) Regulations 1994. Internationally designated Ramsar sites are dealt with in the same way as European sites as a matter of government policy and for the purpose of these rules will be considered as a European Site.

3 SSSI means Site of Special Scientific Interest within the meaning of the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000).

4 Specified AQMA means an air quality management area within the meaning of the Environment Act 1995 which has been designated due to concerns about oxides of nitrogen.
A range of waste types are included in this standard permit including wastes from:

- agriculture, horticulture, aquaculture, forestry, hunting and fishing
- the preparation and processing of meat, fish and other foods of animal origin
- the aerobic treatment of solid wastes
- the anaerobic treatment of waste
- wastewater treatment works
- municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions
- mixed municipal waste

Limits apply to all point source emissions to air and appropriate measures to control other emissions (not controlled by emissions limits) are defined.

**SR2010No16 On-farm AD including use of the resultant biogas**

This standard permit allows an operator to operate an AD facility on-farm for the treatment of wastes (non-hazardous), with use of the biogas, in compression and spark ignition engines, with an aggregate rated thermal input of up to 3 megawatts. The rules also allow the use of standard commercial gas turbines, fuel cells or treatment followed by injection into the gas grid. The total quantity of waste that can be accepted at any site under these rules must not exceed 75,000 tonnes per year.

Any wastes controlled by the Animal By-Products Regulations must be treated and handled in accordance with any requirements imposed by those Regulations. The permitted activities must not be carried out within 200 metres of any off-site building used by the public, including dwelling houses.

In addition to the list of permitted activities applicable for SR2010No15, the rules specify that all activities must be carried out on premises used for agriculture and there is no maximum throughput of animal wastes. The list of wastes that can be treated at this type of facility is much more limited than under standard permit SR2010No15 and is restricted to:

- Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing:
  - sludges from washing and cleaning – food processing waste, food washing waste
  - plant tissue waste - husks, cereal dust, waste animal feeds
  - animal faeces, urine, manure including spoiled straw

- Wastes from the dairy products industry

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5 The full list of waste can be found at: [http://www.environment-agency.gov.uk/static/documents/Business/SR2010No15_Anaerobic_digestion_facility_including_use_of_the_resultant_biogas.pdf](http://www.environment-agency.gov.uk/static/documents/Business/SR2010No15_Anaerobic_digestion_facility_including_use_of_the_resultant_biogas.pdf)
biodegradable materials unsuitable for consumption or processing (other than those containing dangerous substances)
- solid and liquid dairy products, milk, food processing wastes, yoghurt, whey
- sludges from on-site effluent treatment

Limits apply to all point source emissions to air and appropriate measures to control other emissions (not controlled by emissions limits) are defined.

**SR2010No17  Storage of digestate from AD in containers or lagoons**
These standard rules allow the operator to temporarily store waste digestate from AD plants away from the treatment facility. The permit allows the following activities:

- Temporary storage of digestate or liquor in a lagoon or container
- Waste shall not be stored on site for longer than three years
- No emission from the activity shall give rise to the introduction into groundwater of any hazardous substances
- No emission from the activity shall give rise to the introduction into groundwater of any non-hazardous pollutants so as to cause pollution.
- For substances other than hazardous substances or non-hazardous pollutants, the operator shall ensure that all appropriate measures are taken to prevent or where that is not practicable to reduce emissions to groundwater from the permitted site
- The maximum quantity of waste accepted shall not exceed 75,000 tpa
- The maximum storage capacity of the site shall not exceed 75,000m³

**2.5.1 Planning aspects**
In obtaining planning permission for an AD facility, the issues most likely to attract public opposition are noise, odour and vehicle movements.

The Localism Bill was introduced to Parliament in December 2010 and has the aim of moving power away from local government to individuals, communities and councils. It will include significant changes to the planning system including neighbourhood planning. The planning and regeneration provisions will:

a) Abolish Regional Spatial Strategies
b) Abolish the Infrastructure Planning Commission and return to a position where the Secretary of State takes the final decision on major infrastructure proposals of national importance
c) Provide for neighbourhood development orders to allow communities to approve development without requiring normal planning consent

The proposed Localism Bill will include significant changes to the planning system.
Currently, the Planning Act 2008 creates a system of development consent for
nationally significant infrastructure projects and includes projects in the waste
and energy sector.

Planning Policy Statement 10 (PPS10) ‘Planning for Sustainable Waste
Management’ defines how the planning system can contribute to sustainable
waste management. It includes the principles of ‘the Best Practicable
Environmental Option’ (BPEO), regional self-sufficiency, the proximity
principle and the waste hierarchy when considering the location of waste
management facilities. Along with the other planning policy statements it
should be taken into account by regional planning bodies when preparing
regional spatial strategies, and by local planning bodies in the preparation of
local development documents.

When developing a waste treatment facility an environmental statement
including a technical section must be submitted to the relevant planning
authority.

PPS22 sets out the Government’s policies for renewable energy including
biomass. It covers large and small scale developments and provides guidance
on the location of projects, and the promotion of renewable energy through
reasonable and appropriate spatial strategies or development documents.

It also includes the recommendation that local planning authorities and
developers consider the opportunity for incorporating renewable energy
projects such as combined heat and power schemes and biomass heating
into all new developments.

Specifically in relation to biomass projects, PPS22 covers the increase in
traffic which may result from the need to transport crops or other feedstocks to
the energy production plant. It states that local planning authorities should
make sure that any effects of increased traffic are minimised by locating
generation plants as close as possible to the sources of biomass feedstock.
However, PPS22 also recognises that in determining planning applications,
planning authorities should recognise that other factors (such as connections
to the grid and the potential to use heat locally) may influence the most
suitable location for such projects.

PPS23 ‘Planning and Pollution Control’ provides guidance on the interaction
between the planning system and the pollution control regimes including the
Environment Act and the Environmental Protection Act. In ‘Developing an
Implementation plan for AD’ published by DEFRA in July 2009 it was
suggested that this needs to be updated to avoid duplication between
planning and environmental permitting processes for AD plants.

In 2009 the Department for Communities and Local Government (DCLG)
carried out a consultation on the permitted development rights for small-scale
renewables and low-carbon energy technologies including AD. The
consultation closed in February 2010 and included the installation on non-
domestic properties of a variety of technologies including structures to house
AD systems on agricultural and forestry land. The DCLG also carried out a summary review which stated that, subject to conditions, AD facilities are already permitted development as set out in Part 6 of the current GPDO and recommend that these rights are defined in any new part of the GPDO which will be applied to small scale renewables and low carbon technologies. These permitted development rights limit an AD facility to agricultural land and allow the erection, extension or alteration of a building as well as excavation or engineering operations up to an area of 465m² and a number of other conditions.

2.6 Existing and planned AD facilities in the West Midlands
The DEFRA AD Framework working groups proposed in March 2010 that in order to allow the AD industry to develop more strategically, it is important for information to be available to measure the success of the industry and to provide guidance regarding where and when AD opportunities are apparent. One way in which this can be realised is through keeping an up to date map of facilities including feedstock tonnage and output information. This is currently undertaken by the National Non Food Crop Centre (NNFCC). It is proposed that the map⁶ should be updated quarterly from September 2011 with the help of WRAP and the Anaerobic Digestion and Biogas Association (ADBA) and should include details of ABPR classification, digestate use and a filter option to view biomethane injection plants.

There are currently 54 anaerobic digestion facilities in the UK including 5 in the West Midlands region (excluding those treating waste water) as detailed in Table 4. None of the West Midlands facilities currently upgrade biogas for grid injection, although some may be modified to do so in the future.

<table>
<thead>
<tr>
<th>Location of AD facility:</th>
<th>Output:</th>
<th>Feedstock:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocyte, Ludlow, Shropshire</td>
<td>200kWₑ</td>
<td>Source-segregated food waste</td>
</tr>
<tr>
<td>Czero Blackmore Park, Hanley Swan, Worcestershire</td>
<td>2,600kWₑ</td>
<td>Silage, crops, residues</td>
</tr>
<tr>
<td>Lower Reule Farm, Gnossall, Staffordshire</td>
<td>1,300kWₑ</td>
<td>Manure, crops, food</td>
</tr>
<tr>
<td>Poplars AD, Cannock, Staffordshire</td>
<td>6,000kWₑ</td>
<td>Source segregated food, other</td>
</tr>
<tr>
<td>Walford Farm, Shrewsbury, Shropshire</td>
<td>100kWₑ</td>
<td>Cow slurry</td>
</tr>
</tbody>
</table>

Table 4: Operational AD facilities in the West Midlands

| None of the AD facilities in the West Midlands currently upgrade biomethane for injection to the grid. |
---|---|

There are now 2 operational examples of AD facilities which upgrade biogas for injection into the UK gas grid. These are described in Section 3.5.

Other sources of information regarding existing facilities include: Environmental Permitting lists, FiT (Feed-in-Tariff) and ROC (Renewables Obligation Certificate) registers, ABPR (Animal-By-Products Regulations) registrations, REA Biofertiliser Scheme and PAS110 accredited operations⁷.

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⁶ http://biogas-info.co.uk/maps/index2.htm
⁷ DEFRA AD Framework Knowledge and Understanding working group, Outputs v4, 2nd March 2011, http://decc.huddle.net/workspace/13886001
2.7 Food producers in the West Midlands

Within the West Midlands area there are a significant number and variety of food and drink manufacturing operations. The location of food and drink manufacturers is shown in Figure 1. This is based on the standard industrial classification (SIC) code used to classify business establishments according to the type of economic activity they are engaged in. Businesses classified as manufacturing food products and beverages (SIC subsection DA 15) are shown on the map along with the number of employees in each organisation.

![Map of food producers in the West Midlands](image)

<table>
<thead>
<tr>
<th>Employees</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>500+</td>
<td>51-100</td>
</tr>
<tr>
<td>201-500</td>
<td>26-50</td>
</tr>
<tr>
<td>101-200</td>
<td>11-25</td>
</tr>
</tbody>
</table>

It is evident from the map that the majority of food and drink manufacturers are located in urban areas such as Birmingham and the Black Country, Telford and Stoke on Trent. However, there are many operations also based in more rural locations around the area.
In 2008, DEFRA and the Food and Drink Federation (FDF) commissioned a report\(^8\) to assess the amount of food and packaging waste arising from FDF member manufacturing sites across the UK during 2006. In 2010 a subsequent report was commissioned to build on the previous study and provide an updated snapshot of the amount and geographical distribution of food and packaging waste arising along with how this waste is being managed. Data were gathered for both 2008 and 2009 from 149 manufacturing sites. The information ascertained for the West Midlands region is shown in Table 5.

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste arising (t)</td>
<td>10,408</td>
<td>6,342</td>
</tr>
<tr>
<td>Waste to landfill (t)</td>
<td>1,443</td>
<td>974</td>
</tr>
<tr>
<td>Waste to landfill (%)</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Waste to thermal treatment with energy recovery (t)</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>Waste to thermal treatment with energy recovery (%)</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 5: Waste in West Midlands region 2008 and 2009

It is worth noting that none of the FDF member organisations responding to the survey were sending their waste to AD at the time of the report.

### 2.8 Biomethane potential in the West Midlands

The production of biomethane for injection to the grid can reduce our reliance on fossil fuels and increase energy security. This potential can be calculated in various ways. The approach taken here is to compare the gas demand in the West Midlands with a typical gas yield from an estimate of our annual waste arisings. Taking food waste alone, the estimated amount of domestic and C&I waste in the West Midlands is 748,000 tonnes per annum\(^5\). This is the amount currently produced – it is important to note that the amount captured by collections would be considerably less.

From this total potential tonnage of food waste, the calorific value of biomethane produced can be calculated based on typical yields and the efficiency of the process. For gas grid injection the efficiency is estimated at 99.75%, which is much greater than that for conversion to electricity via CHP (approx. 40%). The total energy content of biomethane produced from this mass of feedstock is estimated to be 542 GWh per annum.

The West Midlands’ gas demand is detailed in Section 4.1. This shows that the gas demand of the region in 2009 was 47,800 GWh to include both domestic and commercial sectors. Thus we can conclude that if all of the region’s food waste could be utilised in this way, a little over 1% of the demand could be met.

**If all the food waste in the West Midlands was treated by AD to produce biomethane, just over 1% of the region’s gas demand could be met.**

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\(^5\) West Midlands Location Analysis Tool, WRAP.
Food waste is only part of the total waste which could be used for renewable gas production; other feedstocks may include agricultural slurries and manures, and sewage. In a publication by National Grid,\(^\text{10}\) it is estimated that when all feedstocks are considered (on a national basis), the potential lies around 5-18%\(^\text{11}\).

### 2.9 Preferred locations in the West Midlands

The West Midlands Location Analysis Tool is a GIS (Geographic Information System) based software program, developed by Advantage West Midlands for diverting waste from landfill. It identifies the areas where particular wastes are produced and not recycled, and hence is a guide to recycling and waste management opportunities in the region.

![Organic waste arisings in the West Midlands](image)

**Figure 2: Organic waste arisings in the West Midlands**

Figure 2 shows a graphical output from the tool for organic waste arisings in the West Midlands. The dark shades of green indicate the highest potential arisings of organic based on tonnages, plus transport and planning aspects.

### 2.10 Integration with waste water AD

There is currently a great deal of interest in the co-treatment of sewage sludge and organic waste through AD. Sewerage companies are interested in co-

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An introduction to the production of biomethane gas and injection to the national grid

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At present electricity produced from sewage derived gas is eligible for 0.5 ROCs per MWh whilst electricity produced as a result of the anaerobic digestion of organic waste qualifies for 2 ROCs per MWh.

The Animal By-Products Regulations (Regulation EC 1774/2002 and The Animal By-Products Regulations 2005 as amended) are the main pieces of legislation that will impact on the treatment of municipal wastes at wastewater AD facilities in England. In addition, the control of the solid and/or liquid outputs may also be affected by either the Sludge (Use in Agriculture) Regulations 1989 or the Environmental Permitting Regulations (as amended) also known as the EPR regulations if the output remains a waste.

Currently sewage treatment and end use is dealt with through a separate set of legislation and guidance from commercial and domestic food waste. Where sludge is to be recycled to farm land, the water companies have to conform to the Sludge (Use in Agriculture) Regulations. They also make effective use of the Safe Sludge Matrix, an industry driven quality assurance scheme which defines when, and to what crops different sewage sludge can be applied.

According to DEFRA the Sludge (Use in Agriculture) regulations 1989 are due for revision. However, this has not been done yet and as such the water companies have had some time to develop systems and gain expertise in meeting these regulations in their current format.

If food waste is introduced for digestion in AD facilities designed to treat sewage, this introduces the need to comply with legislation in the form of the Animal By-Products Regulations (ABPR). The ABPR comprise both an EU regulation (EC 1774/2002) and a national regulation that implements the EU regulation in the UK. They impact on a wide range of treatment and end use issues and control how animal by product-containing food wastes can be treated in an AD facility.

If food waste is treated in AD facilities designed to treat sewage, they must comply with the Animal By-Products Regulations (ABPR).

There are a number of key components of the ABPR which have to be taken into account in relation to AD treatment facilities treating food wastes. The ABPR has an impact on the following:

- Method by which food wastes are collected
- Reception of food wastes at a treatment facility, demanding enclosed, bird and vermin proof reception areas
- Layout of the treatment facility demanding separation of ‘clean’ and ‘dirty’ areas
- Process performance dictating either specific time, temperature and particle size profiles to achieve pasteurisation or the demonstration of
prescribed levels of pathogen kill as well as defining secure temporary storage of post digestion material in certain situations

- How the digestate can be used – specifically in relation to use on grazing land
- Management systems, requiring an audit trail to be maintained to track where material is throughout the process and also requiring information to be provided to end users

These issues are already being addressed by existing ABPR compliant AD facilities, but for the wastewater industry certain aspects of the ABPR are likely to pose particular problems where co-digestion is being considered i.e. where an ABPR waste stream is to be co-treated with sewage sludge in an existing waste water AD facility. For example, at present the ABPR regulations would require all material, once mixed with any amount of ABP waste to be pasteurised, or to demonstrate a prescribed level of pathogen kill. This would mean that once mixed with sewage, the whole volume of material being processed would also need to be pasteurised or would have to be shown to have achieved a level of pathogen kill compatible with the ABPR. At present this is not a legal requirement for the sewage if treated on its own.

It is understood that the water industry have been actively engaging with the ABPR regulator Animal Health and DEFRA to see if there is a way to meet the required pasteurisation/pathogen kill requirements of the ABPR without having to adopt a ‘whole stream’ pasteurisation approach.

2.10.1 Ofwat Sustainable Sludge Project and OFT study

The Sustainable Sludge Project has the objective of reviewing the way that sewage sludge activities are regulated and has a number of drivers including the need to reduce the amount of organic waste being sent to landfill and to generate more renewable energy to help mitigate climate change. As part of the Sustainable Sludge Project, Ofwat have requested that the Office of Fair Trading (OFT) carry out a market study.

In January 2011 the OFT announced the market study with the aim of obtaining a greater understanding of developing an effective market for advanced organic waste treatment options including AD and examining whether there are any barriers to efficient investment in the co-treatment of organic waste (i.e. the treatment of combined sewage sludge and municipal organic waste from household or C&I sources) which can be more efficient than separate treatment.

The market study will seek to understand the role that market mechanisms can play in the delivery of sludge treatment, recycling and disposal services and how these services interact with the wider organic waste markets.

If sewerage companies play a greater role in municipal organic waste treatment there may be issues in relation to fairness for their customers and competition across the organic waste treatment sector. For example, the infrastructure and expertise the sewerage companies have access to, paid for
by their customers, could be considered as an unfair advantage in the organic waste market.

It is anticipated that there may be issues regarding incentives and regulation. In a sector subject to regulation, the way in which the market for organic waste services works will be influenced by the incentives created by the regulations. Regulation must take account of the market needs for development and create incentives for investment.

The OFT aims to report in July 2011 and possible results of the market study may include enforcement action by the OFT, a reference to the Competition Commission, or recommendations for changes in laws and regulations. Ofwat will publish their response to the OFT’s recommendations in autumn 2011.
3 Biogas upgrading and grid injection

Natural gas, which is used in the gas grid, contains not only methane but also ethane (between 1% and 15%), propane (between 1% and 10%) as well as smaller amounts of butane and ethene.

In comparison, biogas produced from AD processes contains only 55-60% methane before upgrading and therefore the methane content of biogas is enriched by purification up to 97-98%. During the purification the impurities contained in the raw gas such as carbon dioxide, hydrogen sulphide, oxygen and water need to be removed. The carbon dioxide content in particular reduces the calorific value of the gas.

Once impurities are removed, for biomethane to reach the required calorific value equal to natural gas (roughly 11.3 kWh/m³), it must be blended with a gas with a higher energy content than natural gas (mostly propane).

The Gas (Calculation of Thermal Energy) Regulations 1996 regulates calorific values for gas and it is thought that the injection of biomethane directly to the gas grid may constitute a technical breach of the Regulations because its calorific value is too low.

One of the reasons for increasing the calorific value of biomethane is to ensure that the quality of gas in the grid is consistent and adapted to the consumers' needs. Clarity on issues surrounding propane enrichment including who is responsible and how this will be accounted for in the forthcoming Renewable Heat Incentive (RHI) is required to encourage the development of AD and biomethane injection to the grid.

An odorant must also be added before the gas can be injected into the grid. This gives the otherwise odourless gas its characteristic smell to the gas and is required by the Gas Safety (Management) Regulations. Routine odour monitoring can confirm that acceptable odour intensity is being maintained. Adding odor is an important part of the process from a safety perspective. Too much odorant can lead to increased gas escape reports and too little can lead to unreported gas escapes and explosion risk.\(^\text{12}\)

3.1 Biogas upgrading processes

For this high specification application, biogas will require more pre-treatment to upgrade its quality. This will typically include the removal of oxygen, hydrogen sulphide and moisture, pressurisation, the removal of carbon dioxide, and the addition of propane to increase the calorific value of the biogas. A variety of technologies are available for biogas treatment such as pressure swing adsorption and amine scrubbing or water scrubbing but also systems such as membrane separation or cryogenic separation. The various kinds of biogas treatment include different solutions for scrubbing including water or amine scrubbers and/or polyethylene glycol scrubbing.

\(^{12}\) Technical information for sustainable gas, National Grid, 2011

http://www.nationalgrid.com/uk/Gas/SustainableGasGroup/TechnicalInformation/
The four main reasons for cleaning biogas are:

- To increase the calorific value of the gas
- To align the physical properties of biomethane with the properties of natural gas
- To separate the impurities for machine protection (e.g. engines, boilers and vehicles)
- To reduce the carbon impact of gas utilisation

Removing carbon dioxide increases the calorific value of the gas. However, when removing carbon dioxide from the gas small amounts of methane are also removed. It is important to keep these methane losses low for economic and environmental reasons. There are many commercial methods for reducing carbon dioxide in biogas. The most common methods are absorption or adsorption processes. Other techniques in use are membrane separation and cryogenic separation.

The most common methods for reducing carbon dioxide in biogas are absorption or adsorption processes although membrane separation and cryogenic separation can also be used.

3.1.1 Absorption

Water scrubbing

Water scrubbing is one of the most field tested upgrading/ systems and has been used for more than 10 years. It is a physical cleaning system which utilises the higher solubility of carbon dioxide in water under pressure to separate the carbon dioxide from biogas. This process removes hydrogen sulphide as well as carbon dioxide. In older systems, water scrubbing was a through-feed process with the disadvantage of a large water demand. However, modern systems have been modified so that the carbon dioxide and hydrogen sulphide load will be separated by abrupt decompression and stripped out with air. Due to this modification the scrubbing water can be recycled.

This is the process utilised by Chesterfield Biogas at Didcot in the UK. The most experienced manufacturer of water scrubbing systems is the Swedish company Malmberg.
Amine scrubbing
Carbon dioxide can also be absorbed in a chemical solution containing an amine - the technique is then referred to as amine scrubbing. The most commonly used chemical for this purpose is monoethylamine. Monoethylamine selectively binds carbon dioxide when the biogas meets the liquid in a column. The liquid is then heated until carbon dioxide is released. One advantage with this process is that it can take place at atmospheric pressure.

Chemical scrubbing
Rather than using water, organic solvents like polyethylene glycol and alkanol amines can be used for the absorption of carbon dioxide. Selexol® and Genosorb® are trade names for these chemicals.

The main difference to water scrubbing is that carbon dioxide and hydrogen sulphide are far more soluble in organic solvents than in water and therefore a smaller upgrading plant can be built to treat the same gas capacity.

The main advantages of absorption are the high quality of the resulting biogas and the relatively low levels of fugitive methane emissions in comparison to other biogas clean-up methods.
However, the key disadvantages of absorption are the need for pre-treatment including drying, the continuous loss of washing liquid and therefore associated cost of replacement, the need to dispose of washing liquid, the requirement to use chemicals and the relatively high operating cost and parasitic load in terms of heat and electricity.

3.1.2 Pressure Swing Adsorption (PSA)

In this technique methane and carbon dioxide are separated from each other by using their differences in size and physical properties. Carbon dioxide, oxygen, nitrogen and water are adsorbed on zeolites or activated carbon under increased pressure. The adsorption material is then regenerated by lowering the pressure. The column works in four different phases in which the pressure is changed, hence the name of the technique. In the first phase the carbon dioxide is adsorbed on the material under high pressure, then the pressure is lowered in two steps followed by the last phase in which the pressure is built up again. Investment costs may be relatively moderate and there is little requirement for chemicals, other than the activated carbon.

However, the key disadvantages of PSA are the higher rates of fugitive methane emissions relative to other methods of biogas clean up (<0.5%), and the requirement for pre-treatment for hydrogen sulphide removal.

![Figure 5: Pressure swing adsorption](image)

3.1.3 Membrane separation

Separation is driven by the varying permeability of molecules of different sizes. Membrane separation can either involve a gas phase on both sides of the membrane (sometimes referred to as dry membranes) or it can be a gas/liquid absorption which means that a liquid absorbs the carbon dioxide diffusing through the membrane. The liquid may be an amine.

Other important factors for separation are the pressure difference between the two sides of the membrane and the temperature of the gas. Carbon dioxide and hydrogen sulphide pass through the membrane to the permeate side whereas methane is retained on the inlet side.
Figure 6: Membrane separation

The main advantages of membrane separation are the dry nature of the process and therefore the fact that there is no process water and no waste water.

The key disadvantages of membrane separation are the requirement for pre-treatment for hydrogen sulphide removal, the requirement for high process pressures, high energy requirements and relatively high investment costs.

3.1.4 Cryogenic separation

The cryogenic technique is based the lower boiling point of methane (-161 °C at 1 atmosphere) in comparison to carbon dioxide (-78.5 °C at 1 atmosphere). When the carbon dioxide changes phase methane can be removed. If the gas is further cooled, biogas can be obtained in liquid form which has a density that is 600 times higher than the gas.13

This process is being used in the UK by Adnams brewery in Southwold.

3.2 Legal and regulatory framework

The gas industry is licensed under a regime that is in accordance with the Gas Act of 198614 (as amended). The Act sets out how the industry is regulated and licensed. The regulatory authority which oversees the system of licensing and seeks to ensure a fair deal for the consumer is Ofgem.

The gas industry is regulated in accordance with the Gas Act 1986. The regulatory authority for the gas industry is Ofgem.

The licensing regime follows the flow of gas from the point of production to the point of consumption and can be summarised as follows:

- **Producers** are licensed by the Department for Energy and Climate Change (DECC) because hydrocarbon rights are vested in the Crown.

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However, in the case of biomethane production hydrocarbon and mineral rights do not arise. Therefore producers of biomethane do not need a licence from either DECC or Ofgem.

- **Gas transporters (GT)** who provide the pipelines through which the gas is conveyed are licenced by Ofgem.

- **National Grid Gas Distribution plc.** is licensed as a Transmission System Operator (TSO) to own, operate, develop and maintain the high pressure National Transmission System (NTS). They are also required to undertake energy balancing gas entering and leaving Great Britain’s on-shore pipeline system or network.

- **Gas Distribution Networks (DNs)** operate from the NTS to the end consumers. There are eight licensed organisations which are owned by four companies; National Grid Gas Distribution, Northern Gas Networks, Scotia Gas Networks and Wales and West Utilities. There are also a number of smaller Independent Gas Transporters (IGTs).

- **Shippers** make the arrangements between the GT’s and the producers of supplies via the pipelines and are licenced by Ofgem.

- **Suppliers** sell the gas to the domestic and non-domestic consumers and are also required to be licenced by Ofgem. It is worth noting that the supply and shipping function are often carried out by the same entity. However, there is no contractual relationship between the GT and the Supplier. It should also be noted that a party making arrangements to put biomethane into the gas grid must be a licensed Shipper. Furthermore, under the legislative framework a legal person may not hold both a GT license and a Shipper of Gas supply license.

Under the Gas Act the Health and Safety Executive (HSE) are responsible for overseeing the safe operation of the gas supply system. The HSE are currently actively engaged in the process of developing an appropriate response to the development of the AD sector in the UK, including injection of biomethane into the grid. The groups working with DEFRA in the development of the AD Strategy and Action Plan stressed the paramount importance of health and safety as an integral part of the development of the AD industry in the UK.

### 3.3 Biogas use life cycle comparison

It is important to quantify the benefits in terms of saved emissions to the environment from different biogas uses. Software such as the Waste and Resources Assessment Tool for the Environment (WRATE) administered by the EA is widely used for the life cycle analysis of greenhouse gas emissions from waste treatment technologies such as AD. However currently neither the ‘standard’ nor ‘expert’ versions of this tool can model a gas upgrading process. It is possible that this may be addressed in the future, although it is unlikely that this will be a feature of the next version to be issued later in 2011.
In comparing gas injection, electricity production and transport fuel, two variables are particularly important:

1. The efficiency with which biogas from the digesters is converted to its product (either biomethane, electricity or transport fuel)

2. The extent of emissions which are avoided by using the biogas as a product

**Efficiency**

Depending on the source and type of the feedstocks fed into an AD facility, the yield of biogas per unit weight of input will vary, as will the proportion of methane in the biogas, from as low as 52% to as high as 75%. The methane content will determine the energy potentially available from the biogas but the subsequent end use will determine how much of this energy can actually be included in the final product.

**Biogas methane content can vary from 52-75% depending on the type of feedstocks treated by AD**

In addition it is important to consider the parasitic load and losses that are associated with different biogas uses. Gas clean up technology for biomethane injection and transport fuel has a higher parasitic load than CHP which reduces their net carbon benefit.

**Carbon displacement**

One of the key benefits of AD is that in addition to waste being treated, useful products are also formed. These products vary in how beneficial they are in terms of displacing greenhouse gas emissions from other industries.

Therefore, it can be seen that the eventual carbon displacement figure is not a property of the biogas, but a property of the fuel that it displaces when it is eventually used.

The carbon displacement value of the energy produced by an AD facility will be dependent on the end use that the energy will be put to. DEFRA publishes energy conversion factors. Those relevant to the end uses of biogas considered here are shown in Table 6.

<table>
<thead>
<tr>
<th></th>
<th>kg CO₂ / kWh</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>0.185</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Transport Fuel</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

*Table 6: Energy conversion factors*

The Carbon Trust have published a report based on a model developed by ORA which compares the emissions for biomethane injection, electricity from CHP and upgrading biomethane to be used as a transport fuel.

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15 2010 Guidelines to Defra / DECC’s GHG Conversion Factors for Company Reporting 6th October 2010
16 Biogas from Anaerobic Digestion, Carbon Trust, 1st April 2010
http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTC773
The Carbon Trust found that when accounting for both the efficiency of biogas upgrading and the carbon displacement figures in Table 6, using biomethane as a transport fuel provided the best saving for 2010 with electricity being the next best option. The current savings for gas to grid are lower. This is because the natural gas it replaces is a relatively low carbon fossil fuel, and this technology has a relatively high parasitic load.

The 2020 scenario shows a reduction in the savings associated with electricity production, as a displacement value of 0.31 kg CO$_2$/kWh is used (this is the Committee on Climate Change’s target) which represents lower emissions from displaced electricity as more renewables are used. Therefore it can be seen that looking into the future, biomethane to grid can provide a good choice of technology from a carbon savings point of view.

3.3.1 Green Gas Certification Scheme

The Green Gas Certification Scheme (GGCS) is a voluntary scheme administered by Renewable Energy Assurance Ltd (REAL), a wholly-owned subsidiary of the Renewable Energy Association. It is hoped that the GGCS will be a reliable method of ensuring that there is no double-counting or selling of biomethane and therefore give confidence to consumers in the biomethane sector, and incentivise biogas producers to inject gas to the grid rather than use it to produce electricity.

The GGCS is a web-based system designed to provide a means of tracking contractual flows (as opposed to physical flows) of biomethane through the supply chain. It tracks the biomethane from its injection into the gas grid and sale to a supplier or trader, through to its sale to an end-use consumer.

The Green Gas Certification Scheme tracks contractual flows of biomethane from injection to the grid to the end user

[Figure 7: CO$_2$ savings for a theoretical facility in 2010 and 2020 (Source: Carbon Trust¹⁷)]

¹⁷ http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTC773
Each kWh of biomethane is electronically marked with unique identifier or Renewable Gas Guarantee of Origin (RGGO) which contains information about the following:

- Technology and feedstock from which it was produced including:
  - Agricultural activities
  - Food waste
  - Municipal solid waste
  - Domestic waste water treatment
  - Industrial waste water treatment
  - Combinations of these feedstocks
  - Other feedstocks
- Month and year of production
- Where in the UK it was produced (England, Wales, Scotland, N. Ireland)
- Registered producer

Once a licensed supplier registers a sale of gas to a consumer, an electronic Green Gas Certificate is issued in the consumer’s name. The Certificate guarantees that the equivalent amount of biomethane has been injected into the gas grid. The flow of RGGO’s and Certificates through the gas supply system is summarised in the flow diagram shown in Figure 8.

![Figure 8: GGCS Flow Diagram (Source: GGCS website)](image)

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16 http://www.green-gas.org.uk/scheme/flow-diagram
Participants in the scheme are required to pay an annual membership fee currently at £500 per year and participating licensed gas suppliers are required to pay an annual gas volume fee of 0.04p per kWh on aggregate sales of green gas to end-use consumers in a given month.

3.4 Preferred pipe sizes and pressure constraints.

The size of the pipe required to convey the gas is dependent on a number of factors including:

- Peak expected gas supply from the biomethane plant and the distance the gas is to be conveyed (which, in conjunction with pipe diameter determines the maximum pressure drop from the source to the existing gas network).
- Size, operating pressure and configuration of the pipes in the existing network to which the biomethane plant is to be connected.

The pressure of the natural gas grid and the biomethane is very important. In order to convey the gas from the producer to the consumer there has to be a pressure gradient which is highest at the point of entry into the gas grid and lowest at the point of consumption. This is analogous to the flow of water downhill from a reservoir to the tap in a home or business.

The maximum operating pressure for each pressure tier is as follows:

- National Transmission system (NTS)
  - 70-85 bar
- Local Transmission System (LTS)
  - 7 (ranging between 15-40 bar, most commonly 20-30 bar)
- Intermediate Pressure System (IPS)
  - 2-7 bar
- Medium Pressure System (MPS)
  - 75 mbar – 2 bar
- Low Pressure System (LPS)
  - <75 mbar

At each step there is a depressurisation process which reduces the pressure of the gas entering the next stage to a safe level for the pipeline and ultimately the consumer of the gas.

The low pressure part of the grid supplies domestic properties and some commercial and industrial loads. Other higher demand consumers such as factories and hospitals may be supplied by the medium and intermediate pressure systems, or even the LTS. Some power stations are connected directly to the NTS.

As part of determining the feasibility of injecting the biomethane at a particular point in the gas grid, the producer is required to approach National Grid, who
then undertake a “Capacity Assessment”. As part of this exercise an assessment is made of the supply and demand of gas in this part of the gas grid. In simple terms the lowest demand is assumed from consumers and this is used as the baseline against which the injection of biomethane into the grid is evaluated. If the input rate of biomethane is greater than the expected minimum local demand then the requested input rate will not be possible on a continuous basis. In practice this means that in most locations the low pressure network is unsuitable for the injection of biomethane due to insufficient local demand (typically from domestic properties). As AD plants commonly operate all year round with relatively steady production of biogas it is typically not possible to overcome this problem by restricting the flow of biomethane into the grid. A more appropriate solution is to inject the biomethane into the medium or intermediate pressure parts of the grid.

These parts of the grid, as can be seen above, operate at a wider range of pressures, and (particularly the IPS) typically serve a larger, more diverse demand than the LPS, and therefore are more likely to be able to accommodate the output from the biomethane plant.

However, in order to deliver biomethane into the grid at higher pressures it may be necessary to use a compressor to raise the gas pressure to a level which can allow it to enter the grid. This will be dependent on the pressure tier into which it is proposed to deliver the biomethane and the method of upgrading the biomethane. For example, upgrading using the chemical wash process takes place at a lower pressure than upgrading using the pressure swing adsorption or water wash processes.

In order to allow the grid to be more accommodating to decentralised biomethane injection National Grid and other GDNs are currently reviewing the potential to allow the gas to be moved up the pressure gradient within the gas grid. For example if there is insufficient demand in the local MPS to accommodate the output from the biomethane plant at all times in the year, with some modification to the system it may be possible to pump it from the MPS system into the IPS system where the demand is more diverse and storage capacity is greater. This would be achieved by installing compressors at the appropriate pressure reduction station. This system has been successfully trialled in Austria and Germany and National Grid and another GDN are planning to undertake network modelling and experimental work to prove the concept for use in the UK.

Biomethane that is injected into the gas network must meet the gas quality standards set out in the Gas Safety (Management) Regulations, and in addition there is industry agreement that its energy content must be made comparable with that of the gas in the local network. However, if the proportion of injected biomethane is low relative to the pipeline gas, in some circumstances the HSE has agreed that it may be possible to meet the requirements in relation to oxygen content by blending with pipeline gas. Discussions are continuing with the HSE on the possibility of relaxing the maximum oxygen concentration currently specified in GSMR. Discussions are also continuing with Ofgem on whether blending might also be an option to
achieve acceptable energy content and so avoid the need to enrich the biomethane with propane.

**Biomethane injected to the gas grid must meet the quality standards set out in the Gas Safety (Management) Regulations, and its energy content must be comparable to the gas in the local network**

Another option which is being considered is the establishment of local Biogas pipelines which could possibly link smaller AD plants which themselves would not have sufficient biogas production to make biomethane production cost effective. Upgrading to biomethane would then take place at a central point prior to injection into the main gas distribution network. This approach has been developed in Germany.

### 3.5 UK Reference projects

In the UK there are currently two operational AD facilities where biogas is upgraded to biomethane for injection to the gas grid.

#### Didcot sewage works

The joint project between Thames Water, British Gas and Scotia Gas Networks utilises biomethane gas from Didcot sewage works in Oxfordshire for injection to the grid. This project uses the water scrubbing method of upgrading biogas.

#### Adnams Brewery

Adnams Bio Energy, in partnership with National Grid and British Gas, treats up to 12,500 tonnes per annum of brewery and local supermarket food waste via anaerobic digestion, producing biomethane which is injected into the grid. The plant is located in Southwold in Suffolk and has been operational since October 2010. It is projected that 40% of the gas produced will be used to power the Adnams brewery and run its vehicles, with the other 60% being available for injection into the National Grid after a cryogenic upgrading process.

The project was part funded by the European Regional Development Fund (ERDF) at £1.18 million, the East of England Development Agency (EEDA) and DECC.
4 UK Gas Supply Profile

Gas producers deliver gas to nine terminals from offshore fields and via pipelines from Norway, Holland and Belgium. Liquefied Natural Gas (LNG) is delivered by ship. UK Continental Shelf (UKCS) production of natural gas has been decreasing for over ten years as a result of depleting reserves. Since 2000 gas production has declined at a rate of just over 6% per annum. The UK has been a net importer of gas since 2004. In 2009, 58% of the UK’s gross gas imports were from Norway. 58% of the UK’s exported gas was to continental Europe and 42 per cent to the Republic of Ireland. Total indigenous UK production of natural gas in 2010 was 4.3 per cent lower than in 2009.

The expansion of LNG terminals at the Isle of Grain in late December 2008 and the commencement of South Hook and Dragon at Milford Haven in 2009 increased the UK’s LNG import capacity to approximately 50 bcm at the end of 2010. LNG is imported from Algeria, Trinidad and Tobago, Qatar, Egypt, Norway, the USA and Australia. Grain LNG has storage availability of one million cubic metres, equivalent to more than two days’ worth of average UK gas demand. LNG imports are seen as increasingly important in meeting the UK’s gas demand. Import and export routes for natural gas in 2009 are shown in Table 7 and Figure 9.

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>IMPORT</th>
<th>EXPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium (via Bacton-Zeebrugge interconnector)</td>
<td>7,945</td>
<td>62,084</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>69,529</td>
<td>13,094</td>
</tr>
<tr>
<td>Norway</td>
<td>260,438</td>
<td>276</td>
</tr>
<tr>
<td>LNG (to the Isle of Grain and Gasport Teesside)</td>
<td>110,579</td>
<td>0</td>
</tr>
<tr>
<td>ROI</td>
<td>0</td>
<td>54,355</td>
</tr>
<tr>
<td>TOTAL (GWh)</td>
<td>448,491</td>
<td>129,809</td>
</tr>
<tr>
<td>NET IMPORT (GWh)</td>
<td>318,682</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Natural gas imports and exports 2009 (Source: DECC)

![Figure 9: UK gas supply network (Source: National Grid)](image-url)
From the terminals, gas enters the high-pressure national transmission system (NTS) operating at pressures of up to 85 bar (over 1250 psi). Gas is pushed through the system using 23 compressor stations. The NTS supplies gas to UK end consumers from over 175 off-take points. This includes large end users such as industrial consumers and power stations, who receive gas directly from the NTS rather than through a distribution network, and the twelve local distribution zones (LDZ) that contain pipes operating at lower pressure supplying smaller end consumers.

In relation to forecasts of European supplies of gas to the UK there is uncertainty regarding the potential levels of each source. However at a high level, there are a number of key messages:

- European indigenous production is in long term decline as there are few opportunities for new gas discoveries.
- Supplies from Norway are forecast to increase to 2015, followed by a production plateau for a number of years before entering a period of gradual decline. If there was a significant new find within the next decade in the North or Norwegian Sea then there could be further upside.
- There is considerable uncertainty regarding Russian supplies to Western Europe.
- LNG and other imports are likely to have growth potential.
- Pipeline gas will continue to be the main supply source into Europe, with most of the increases from Russian and possibly the Caspian region. LNG supplies will also grow over the forecast period, with LNG imports satisfying about 20-25% of total OECD Europe demand.

Forecasts of future supplies by National Grid include a contribution for unconventional gas (from biogas and coal bed methane (CBM) however there is much uncertainty over the level of contribution that they will provide. In their 2050 pathways analysis DECC indicate that in the long term it is likely that natural gas boilers will be phased out as part of efforts to decarbonise heating thus largely removing the need for a natural gas grid. However the introduction of biomethane as an alternative heating fuel could allow some parts of the gas grid to remain in use. The analysis identifies possible constraints on the use of biogas for heating as being:

- Uncertainty over future volumes of biomass and organic waste
- High demand for biogas from other sectors of the economy, particularly transport where use of biogas as a fuel is possible
- Injection into the high pressure gas grid may be problematic due to the higher oxygen concentration compared to natural gas

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Gas storage
Gas storage capacity is important to cover peaks in gas demand and to manage the UK’s increasing reliance on imported gas. This is also discussed in Section 4. In the UK gas is stored onshore in two types of underground storage (UGS) facility:

1. Strata of former oil and gas fields, where gas is injected back into the reservoir from which oil and/or gas has been removed. Gas stored in this manner takes time to extract and so is mainly used to meet seasonal demand over the winter months.

2. Salt cavity storage whereby cavities are created in underground salt strata by dissolving salt and filling the void with gas. Gas stored in salt cavities can be extracted more quickly, and is therefore used to meet peak demand periods.

There are seven operational UGS facilities in the UK at:

- Rough (offshore Southern North Sea) - the UK’s largest offshore storage facility around 18 miles off the east coast of Yorkshire linked to the Easington gas terminal. The Rough facility can store 3.3 bn cubic metres of gas.
- Aldbrough and Hornsea (East Yorkshire) - in which around 3.25 bn cubic metres (mcm) of gas can be stored
- Hatfield Moors (Yorkshire)
- Humbly Grove (Weald in Hampshire)
- Holford and Hole House Farm (Cheshire)

LNG is also stored in large storage tanks situated at strategic parts of the gas network. Operational LNG storage facilities are located at:

- Avonmouth (near Bristol)
- Partington (near Manchester)
- Glenmavis (Strathclyde in Scotland)
- Waterston (Milford Haven in Wales)
- South Hook (west Wales)
- Isle of Grain (Kent)

Significant increases in storage capacity/deliverability are planned or being considered at existing or new sites, both onshore and offshore. In September 2010 the Secretary of State approved a new gas storage project at Saltfleetby Gas Field in Lincolnshire with a capacity of over 700 million cubic meters.

Centrica and Perenco UK plan to develop an offshore gas storage facility in the Baird field with capacity of 2.36 bn cubic metres. This would be the second-largest gas storage facility in the UK. As part of the development North Norfolk District Council has granted planning permission for a pipeline reception and gas compression building at the Bacton terminal.
Competition in the gas supply industry
When British Gas was privatised in 1986, it was given a statutory monopoly over supplies of natural gas to premises taking less than 732,000 kWh a year. Customers taking more than this were able to buy their gas from other suppliers, but no other suppliers entered the market until 1990.

In 1991, the OFT reviewed progress towards a competitive market, and found that previous steps had been ineffective in encouraging competition. In 1992 British Gas undertook a number of steps to encourage competition alongside the Government who also took powers to reduce or remove the tariff monopoly, and lower the tariff threshold.

In 1995, the Gas Bill received Royal Assent allowing for the phased extension of competition into the domestic gas supply market between 1996 and 1998. British Gas was fully separated into two corporate entities and in October 2002, Transco and the National Grid Company merged to form National Grid.

From October 2001 gas pipeline companies have been able to apply for their own Gas Transporter Licences so that they can compete with Transco.

Competition in the domestic market remained mainly unchanged between 2007 and 2009, with the largest three suppliers accounting for 71% of sales in 2009. At the end of May 2010, 44 suppliers were licensed to supply gas to domestic customers.

Gas distribution
Gas distribution is the process where gas is taken from the high pressure transmission system and distributed through low pressure networks of pipes to end users.

There are eight gas distribution networks (GDNs) in Britain, each covering distinct geographical regions. In addition there are several smaller networks owned and operated by Independent Gas Transporters (IGTs). Most IGT’s have been built to serve new housing. Existing GDN’s monopolies along with IGTs are regulated by Ofgem.

In order to distribute gas a GDN and IGT must hold a licence which contains conditions, including a limit on the amount of revenue which these companies can recover from customers.

In June 2005 National Grid Gas plc sold four of the eight GDNs to Scotia Gas Networks (which owns Southern Gas Network and Scotland Gas Network), Northern Gas Networks and Wales & West Utilities. The coverage of these GDN’s is shown in Figure 10.
Gas demand
In 2010 gas demand increased when compared with 2009 with greater exports to continental Europe via the IUK interconnector and increased power generation demand, mainly due to relative fuel prices. Demand for gas in 2010 as a whole was 8.3% higher than in 2009. In 2010 domestic consumption increased by 15% reflecting the colder weather, and consumption in the industrial sector increased by 8.9%\(^\text{21}\). In 2009\(^\text{22}\) natural gas demand in the UK was as shown in Figure 11.

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In the industrial sector the largest consumers are the chemical, food, mineral products and paper making industries. The chemicals sector accounted for almost 25% of the industrial consumption of natural gas.

Gas use in the domestic sector is especially dependent on winter temperatures. However the poor economic climate and increasing energy efficiency measures may offset the effect of colder winter temperatures on domestic gas demand.

The past three years have seen volatility in both the energy and global financial markets. This has resulted in gas prices reaching record levels and a rapid decline in the UK economy, resulting in a recession. The effect of the economic downturn on energy demand has been significant with a decrease in gas demand in the traditional market sectors of 7% on the previous year in 2009.

The following two maps indicate the average domestic and non-domestic gas consumption (kWh per meter point) in 2009. It is interesting to note the differences between domestic consumption in the north and south of the UK which is likely to be partly related to average temperatures.

Figure 12: Average domestic gas consumption per meter point 2009 (kWh) (Source: DECC)
Future of gas and combined heat and power

Combined heat and power (CHP) is the simultaneous generation of usable heat and power (usually electricity) in a single process. CHP uses a variety of fuels with natural gas fuelling 71% of the UK’s CHP in 2009. CHP is typically sized to make use of the available heat, and connected to the lower voltage distribution system (i.e. embedded). This means that unlike conventional power stations, CHP can provide efficiency gains by avoiding significant transmission and distribution losses.

Good Quality CHP schemes are eligible for government support and are those that have been certified as being highly efficient through the UK’s CHP Quality Assurance (CHPQA) programme. A Good Quality CHP plant must achieve 10% primary energy savings compared to the separate generation of heat and power i.e. via a boiler and power station.

There are a range of incentives for the growth of Good Quality CHP in the UK including:

1. Exemption from the Climate Change Levy (CCL) of all fuel inputs and electricity outputs
2. Eligibility to Enhanced Capital Allowances for plant and machinery
3. Favourable allocations of carbon allowances under Phase II of the EU Emissions Trading Scheme
4. Business Rates exemption for power generation plant and machinery
5. Extension of the eligibility for Renewable Obligation Certificates (ROCs) to energy from waste plants that utilise CHP

Figure 13: Average non–domestic gas consumption per meter point 2009 (kWh) (Source: DECC)
6. Increased support under the Renewables Obligation with two ROCs allocated to the electricity output of CHP fuelled by biomass

7. The zero rating of heat under the Carbon Reduction Commitment (CRC) and the associated growth in CHP that is expected

8. Heat from renewable CHP is included in the Renewable Heat Incentive (RHI) if the fuel or technology is eligible. This means biomass (including MSW), biogas and geothermal. In this case CHPQA requirements do not have to be met. There are no restrictions on receiving FITs and RHI for heat (applies to biogas combustion only)

With the expected growth in CHP and the eligibility of heat from renewable CHP for the RHI, the economic viability of biomethane injection to the grid is likely to increase in future years.

**Micro CHP**

Micro-CHP is a form of CHP designed for individual households with electricity being generated for consumption in the home and export to the grid, alongside heat for space and water heating.

In April 2010 the Department of Energy and Climate Change (DECC) introduced a system of feed-in tariffs to incentivise small scale low carbon electricity generation of less than 5MW. Micro-CHP is included at a pilot scale with units of capacity equal to or less than 2 kW included in the FIT with the tariff level at £0.10 per kWh fixed for the next 10 years. The micro-CHP pilot will support up to 30,000 installations with a review to start when 12,000 installations have occurred.

**4.1 West Midlands profile**

National Grid own and operate the gas distribution network in the West Midlands. Gas consumption by domestic and commercial and industrial consumers in the region in 2009 is shown in Table 8.
An introduction to the production of biomethane gas and injection to the national grid Revised Final Report

Table 8: Gas consumption in West Midlands 2009 (Source: DECC)

The gas grid has been designed to accommodate peak demand for gas and there are therefore unlikely to be any major pinch points or bottlenecks in the West Midlands. However, the ability to inject biomethane at particular points in the network will be dependent on the outcome of a “Capacity Assessment” which will have to account for the issues regarding storage capacity and pressure at the point of injection. This will state the limit in terms of m³ per hour that can be injected to the grid.

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<thead>
<tr>
<th>Local Authority</th>
<th>Domestic consumers</th>
<th>C&amp;I consumers</th>
<th>All consumers</th>
<th>Sales per consumer (kWh)</th>
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<td></td>
<td>Sales - GWh</td>
<td>Number of consumers (thousands)</td>
<td>Sales - GWh</td>
<td>Number of consumers (thousands)</td>
</tr>
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<td>Basingstoke</td>
<td>336.3</td>
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<td>130.0</td>
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<td>429.8</td>
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<td>22.6</td>
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ORGANIC RESOURCE AGENCY LTD

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5 Economics

5.1 Economics of AD
The economic case for AD is changing as a result of increasing Landfill Tax, the eligibility of electricity produced from AD for double Renewable Obligation Certificates (ROCs) and the potential for support for injection of biomethane to the gas grid via the Renewable Heat Incentive (RHI) announced earlier in March 2011.

5.1.1 Gate fees
According to the WRAP Gate Fees Report 2010\(^{23}\), the average price for landfill including tax is between £59 and £92 in comparison to the cost of AD which is currently between £50 and £90 per tonne. The rate of Landfill Tax for 2011/12 is £56 per tonne and the Government announced in the 2010 Budget that this will continue to escalate by £8 per year until at least 2014/15, when it will reach £80 per tonne.

In contrast, as more and more AD facilities become operational the associated gate fees are likely to decrease as a result of competition. The combination of potentially lower gate fees for AD and higher costs for landfill is likely to encourage waste producers to consider AD as an economically viable treatment option and may increase the security of supply for feedstocks such as household organic waste.

The cost of AD was between £50 and £90 per tonne in 2010. As more AD facilities become operational the gate fee will decrease as a result of competition.

When considering revenues that may be generated for AD via the application of feedstock gate fees, operators must bear in mind that for some feedstocks they will not be able to charge a gate fee at all. If the feedstock is in great demand as a result of its proximity to the AD facility, if it currently has value to the waste producer (e.g. some wastes from food manufacturing have value as an animal feed), or if it is an energy crop with associated production costs, then the AD operator may have to pay for the feedstock.

5.1.2 Economics of scale
AD plants can benefit from economies of scale. However, it is important to note that the capital and operating cost is not only dependent on tonnage of feedstock which they are designed to treat. It is also heavily dependent on the type of feedstocks which the AD plant is designed to treat.

At the lowest end of the spectrum are facilities that are designed to treat agricultural waste and energy crops. This is because there is usually no need for enclosed reception buildings, and associated air handling systems, and the mechanical pre-treatment is limited. Furthermore, the regulatory requirements are often less stringent e.g. if the material is not handling animal by-products

\(^{23}\) http://www.wrap.org.uk/recycling_industry/publications/gate_fees_2010.html
as defined under the Animal By Products Regulation (ABPR) there a lesser need for enclosure of the plant and no requirement to pasteurise the digestate.

AD plants that treat source segregated municipal waste from household and commercial and industrial sources are typically more costly per tonne of throughput. This is because they are treating ABPR wastes and therefore are required to have enclosed reception, pre-treatment and storage areas. These are often maintained under negative pressure and have associated air handling treatment systems. There is usually a requirement to pass the exhaust air through an emission control facility such as a biofilter. Furthermore, as the material often contains some contrary materials in the form of packaging and non-biodegradable waste there is a requirement to remove this to avoid complications with the AD process and to ensure sufficiently high-quality of the digestate. This all adds to the capital cost of the plant. In addition because the plant is handling a waste there are additional costs in terms of the regulation of the plant under an Environmental Permit. This also applies to the storage and spreading of the digestate which would either have to be done under an Environmental Permit or via the quality protocol and PAS110, both of which incur significant on-going operational costs.

The highest capex is typically associated with AD plants which are included as part of an MBT facility. These plants typically include all of the costs associated with enclosure, air handling and exhaust air treatment. However, because these facilities treat mixed residual waste they normally have high level of complex mechanical pre-treatment to remove recyclable material and material which could damage the AD process. In addition, given the nature of the material which typically has a higher dry matter content, there is commonly a requirement for a heavily engineered AD process, for example including pumps which are built to a high specification and capable of pumping liquid cement. In addition, there is a need for sophisticated pre-treatment and digester tank systems to mitigate the high risk and associated operational problems arising from sedimentation.

Sewage treatment facilities are designed for a different input and output specification. Their primary purpose is to treat very liquid material in order to achieve pathogen kill and odour reduction, and they are often not optimised for biogas production. As a result they often have high throughputs with relatively short hydraulic retention times. Furthermore, they are usually integrated into the water treatment facility in terms of the receipt of feedstock and the storage of output. Consequently it is difficult to compare their costs on a like for like basis with the above solid feedstock treatment AD plants.

AD plants can benefit from economies of scale. Capital and operating cost is dependent on tonnage and type of feedstock which the plant is designed to treat.
Having said this, within each of the above broad generic types of AD plant there are economies of scale which can be achieved. However, it should be noted that AD plants are modular, i.e. to increase capacity additional tanks will be added rather than building a single larger scale tank. Therefore, the economics are stepped as additional tanks are required. The key to success is to allow enough space at the outset to add additional digester tanks and to make sure the associated plant and infrastructure is large enough to accommodate future feedstocks (e.g. reception hall, pre-treatment and storage capacity). This can lead to an over capitalised plant at the outset that benefits from economies of scale as the feedstock throughput increases. The most significant limiting factors on the size of an AD facility are likely to be:

- Supply of feedstock
- Off take contracts for the digestate within an economic distance
- Capacity of the electricity grid, gas grid and possible use of heat
- Site specific issues e.g. space, height restrictions vehicle movement restrictions

The actual cost of facilities is very site specific as this will affect the civil engineering costs associated with construction, for example piling the facility and space restrictions which may demand a more complex design. There is considerable variation between suppliers of the technology in (with the exception of the water industry) a relatively immature market in the UK. In tendering processes ORA has often found a 50% or even higher variation in capex even when a tender is offered for a particular site with a clearly defined input and output specification.

5.2 Economics of gas injection

5.2.1 Capital expenditure
The capital expenditure (capex) required for biogas upgrading equipment, over and above that required for the AD process increases with throughput. However, there are economies of scale and the capex required per unit of gas processed falls with increased throughput. Figure 14 shows this graphically.

![Figure 14: Typical capex per m³ of biogas processed by PSA and amine scrubbing](image-url)
The graphed data is based on continental European facilities, which are generally larger than those in Britain currently. Over this range of European facilities it can be seen that the capex required per m$^3$ of biogas processed, drops by around 20% for pressure swing adsorption technology and around 30% for amine scrubbing. It is estimated that for most European facilities capex for the upgrading technology is in the range of £0.65-£0.80/m$^3$ of biogas upgraded. The minimum size for what may be a financially viable facility depends on many factors. Below a biogas throughput of around 300m$^3$/h, the effect of incentives such as the RHI are critical and the chances that a facility will not be viable are greatly increased.

5.2.2 Cost of connection to grid

The cost of connection is site specific. However it is estimated that currently this cost is in the region of £750,000 which is often seen as prohibitively expensive. The high cost is the result of the high level of monitoring required under the Gas Safety (Management) Regulations 1996 to determine the quality and quantity of biomethane that is injected. These standards could be considered appropriate for injection into the NTS for production from the North Sea gas fields, but excessive for AD plants with biomethane production.

Currently there is a process of consultation underway with the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) to have more appropriate regulation for AD and biomethane injection. It is hoped that this will reduce the cost to around £400,000 including the installation and monitoring. The National Grid are also supporting the concept of “socialising” this cost based on existing precedents with the gas grid between the NTS and the LDS where the shippers do not have to pay costs of this type. For more detail on the gas supply chain please refer to Section 3.2.

Current costs of connection to the grid are in the region of £750,000, largely due to the high level of gas quality monitoring required. It is hoped that in the near future this will be reduced to around £400,000.

5.2.3 Economic comparison of biogas use options

Most biogas produced from AD in the UK is used to produce electricity. However, other than injecting gas to the gas grid, biogas can also be upgraded for use as vehicle fuel. A comparison of these three technologies was conducted by the Carbon Trust, based on a model developed by the ORA$^{24}$. It was found that gate fees in particular had a large impact on the profitability of the plant and that energy incentives such as the Feed in Tariff and Renewable Heat Incentive also play a major role. This is illustrated in Figure 15 which shows the revenues and costs for three scenarios, based on a household food waste feedstock of 25,000 tonnes per annum and a gate fee of £40 per tonne. The incentives utilised are the Feed in Tariff (FIT) (9p/kWh) for electricity production, Renewable Heat Incentive (RHI) (4p/kWh) for biomethane injection and Renewable Transport Fuel Certificates (RTFC) valued at 30p/litre.

$^{24}$ Biogas from Anaerobic Digestion, Carbon Trust, 1st April 2010
http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=CTC773
It should be noted that since this report was published in March 2010, costs and financial incentives have changed, and will continue to do so in the future. In particular, gate fees, which here provide most of the facility’s revenue, are subject to wide variation.

The modelling exercise by the Carbon Trust highlighted that returns to facility developers were found to be similar for the three technologies studied, measured as internal rate of return (IRR) and shown in Figure 16.

However, the announcement in March 2011 of an increase in the RHI payment to 6.5 p/kWh for biomethane injection may tip the balance firmly to favour the gas to grid option.
The internal rate of return associated with an AD facility and biomethane injection plant will be improved as a result of the Renewable Heat Incentive.

5.2.4 Impact of Renewable Heat Incentive
The incentive for upgrading biogas to biomethane for grid injection was previously referred to as the Biomethane Tariff. This is now part of the Renewable Heat Incentive (RHI) which is due to be launched in July 2011. Biogas from AD facilities is eligible, but landfill gas is specifically excluded.

A single tariff rate for biomethane injection has been set at 6.5p/kWh applicable to facilities of all sizes. The same rate applies for biogas combustion but only for facilities of less than 200 kWth. The tariff will remain in place for 20 years and is the rate will remain until a Spending Review reduces the tariff. This is expected in 2014. In the same manner as the Feed-in-Tariff scheme, the RHI tariffs for new installations are expected to fall as the costs associated with each technology lowers. Payments are to be made quarterly, over a tariff lifetime of 20 years, and have been designed to bridge the financial gap between the cost of conventional and renewable heating systems.

Previously the tariff rate for biomethane injection was expected to be 4p/kWh, so the announcement of a rate of 6.5p/kWh should boost uptake and will increase projected internal rates of return (IRR). This will appeal to a larger range of external investors as well as plant developers.

The Renewable Heat Incentive provides a fixed tariff of 6.5p/kWh to biomethane injection facilities of all sizes. This is expected to remain the case until at least 2014.

5.2.5 Planned infrastructure investment
The gas grid is designed to accommodate peak demand across the UK. Gas demand is predicted to fall or at least stabilise due to improving energy conservation and efficiency measures therefore it is unlikely that there will be a requirement for large scale investment in the gas grid. However, in order to improve accessibility to the grid there will need to be an increase in the points at which biomethane is injected to the grid. DECC have indicated that as part of considering the RHI they would welcome around 7 TW of biomethane being injected into the grid by 2020.

Assuming that each biomethane injection facility had the capacity inject 500 m$^3$ of biomethane (approximately equivalent to 5 MW biomethane) then this would require the development of between 160 to 170 plants. If it is assumed that the cost of injection falls to around £400,000 then the total cost would be in the region of £7 million. If a larger number of smaller plants were developed then on this basis there would be a pro rata increase in the total capital cost. In addition to this there may also be investment in compression system to allow the biomethane to be pumped up the pressure gradient in the grid.

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25 Renewable Heat Incentive, DECC, March 2011
gas grid to improve the storage capacity of the grid. The cost of this is difficult to estimate as it will be site specific. There appears to be increasing cross industry consensus that these costs should be "socialised" rather than being charged to the individual developer.

In addition there will be the capital cost of the AD and biomethane production plants themselves.

5.2.6 Carbon floor price
The purpose of the carbon price floor is to encourage additional investment in low carbon power generation by providing greater support and certainty to the carbon price. The Government anticipate that the carbon floor price should drive £30-40 billion of new investment in the low carbon sector, increasing low carbon capacity to 7.5 to 9.3 GW. Greenpeace and the WWF have commented that this will lead to £3.43bn "windfall" profits for existing nuclear power generators. It remains to be seen how much influence this will have on the development of AD and biomethane injection to the grid in particular.

The Government announced in its budget on March 23rd 2011 that a carbon floor price for the generation of electricity will be introduced from 1st April 2013. They indicated that the floor will start at around £16 per tonne of carbon dioxide and increase linearly to £30 per tonne in 2020 in order to drive investment in the low carbon power sector. The carbon price support rates for 2013/14 will be equivalent to £4.94 per tonne of carbon dioxide.

5.2.7 Trends in gas prices and International drivers
Estimates from the International Energy Agency (IEA) predict that, under a business as usual model, global gas demand will increase by 42% between 2008 and 2030, from approximately 2,800bcm to 3,900bcm. Non-OECD countries account for 81% of this growth, with China and India both expected to grow at over 5% per year (albeit from a low base).

Global gas demand will increase by 42% between 2008 and 2030 with non-OECD countries accounting for 81% of this growth

Global gas production growth is expected to be driven almost entirely from non-OECD countries; OECD production is in fact predicted to decline absolutely and proportionately from 37% of global production in 2007 to 27% in 2030. The proportion of Middle Eastern production is expected to increase from 12% to 19% over the same period, while Russia’s share falls from 21% to 18% (though it remains the single largest producer). Over 50% of present gas reserves are located in three countries: Russia (23%), Iran (16%) and Qatar (14%)26.

Data included in the National Statistics Quarterly Energy Prices Report for December 2010 show that over the five years from 2004 to 2009 average industrial gas prices increased by 98% (75% in real terms), with a decrease of 10% in 2009.

It is difficult to predict future trends in gas prices especially given current events in the Middle East in particular and the difficulties experienced in oil and gas extraction in more challenging environments, as for example witnessed by BP in the Gulf of Mexico. However in the National Statistics Quarterly Energy Prices December 2010 it is reported that from 2004-2009 average gas prices have increased by 98% which is equivalent to 75% in real terms, with a 10% increase in 2009 (11% in real terms).

6 Future of AD and biomethane injection

The Coalition Government are working with DEFRA and published the AD Strategy and Action Plan on the 14th June 2011. The work that was undertaken to develop this framework was informed by, and will inform other existing Government initiatives including the Government's vision of localism where power is decentralised to the lowest possible level, shifting power away from central government to individuals, communities and councils. The Strategy makes clear that the Government and its partners are committed to facilitating biomethane injection into the national gas grid, and the use of biomethane as a transport fuel.

The AD Strategy and Action Plan makes clear that the Government and its partners are committed to facilitating biomethane injection into the national gas grid

The Electricity Market Reform is the government’s preferred electricity market framework including objectives on decarbonisation, renewable energy, security of supply and affordability. The consultation was open until 10th March 2011 and the White Paper including legislative proposals to implement the new electricity market arrangements will be launched in Late Spring 2011. The Electricity Market Reform Project will develop and deliver a new market framework that will enable the delivery of secure supplies of low carbon energy. The consultation document states that by 2020 around 30% of our electricity should come from renewable sources in order to meet the legally binding EU target for renewable energy. The consultation also confirms the intention of the government to continue grandfathering (i.e. maintaining a fixed level of support for the full lifetime of a generating station’s eligibility for the Renewables Obligation, from the point of accreditation) anaerobic digestion and dedicated biomass plants using solid biomass or biogas.

The UK Low Carbon Transition Plan published by the previous Labour Government in July 2009 sets out a series of steps required to deliver emissions reductions of 18% on 2008 levels by 2020. The White Paper highlights the potential of AD for the transformation of food waste, sewage sludge and agricultural waste into biogas and renewable energy, whilst reducing emissions of greenhouse gases through diversion from landfill and more effective manure management. This potential is also stressed in The UK Renewable Energy Strategy also published in July 2009.

6.1 Energy Act 2008

The Energy Act 2008 covers renewable energy and via the Renewables Obligation introduced different support levels (or banding) for renewable technologies in April 2009. AD is among the technologies that receive additional support in the form of multiple Renewable Obligation Certificates (ROCs) with 2 ROCs/MWh of electricity produced. The Act has also resulted in the introduction of feed-in tariffs allowing the Government to offer financial

support for low-carbon electricity generation for smaller scale projects up to 5 megawatts (MW).

The main driver for an increase in injection of biomethane to the grid is expected to be the Renewable Heat Incentive, the details of which were announced in March 2011 and are discussed in Section 5.2.4.

6.2 Funding for AD in the West Midlands

Within the West Midlands region funding opportunities exist for organisations wishing to invest in new or expanded food waste treatment which could include AD with the production of biomethane.

6.2.1 Capital grants (EWM100)

The purpose of the capital grant programme is to provide grants to Small or Medium Enterprises (SMEs) towards the costs of plant and equipment for projects that will significantly increase the quantity of C&I waste arisings diverted from landfill. There is particular emphasis on food waste along with several other waste materials. Projects which recover energy from waste are eligible provided the material could not be readily reused or recycled by other means and that the technology is proven or can be demonstrated by existing operational reference plants.

WRAP has a total budget of £2.5 million for the programme and projects are selected via a competitive process with applications evaluated against defined criteria. The deadline for applications is 26th March 2011 and the outcome of the capital investment must be operational by 31 March 2013.

6.2.2 De-minimis funding (EWM200)

AWM has awarded WRAP £4.2m of European Regional Development Fund (ERDF) to continue investment in recycling infrastructure in the West Midlands until 2012. The focus is on increasing collections of waste, developing recycling infrastructure and encouraging the use of recycled materials in manufacturing.

This support includes grant funding of up to 50% (to a maximum of £100,000) of total eligible capital costs for businesses investing in new or expanded C&I waste collection, recycling and/or reprocessing capacity. This support is offered under an element of European Community State Aid rules known as de minimis (EC regulation 69/2001 – ‘de minimis’ aid regulation). De minimis regulations allow provision of financial support of up to €200,000 (around £172,040) per company within a rolling three year fiscal period.

The focus is on specific waste materials including food waste. There is no closing date for applications, although the Programme closes at the end of March 2012 and no further funding will be available beyond this date.

6.2.3 Rural Development Programme for England (RDPE)

The Rural Development Programme for England (RDPE) is a funding scheme available to land based businesses (including farmers, growers, foresters, and
primary processors), rural tourism organisations and other small rural businesses. The objective of the RPDE is to safeguard and enhance the countryside, to improve the competitiveness and sustainability of rural businesses, and to help communities to thrive. The programme runs until 2013 and is jointly funded by the EU Agricultural Fund for Rural Development (EAFRD) and the UK Government. AWM has a budget of £53 million to deliver the social and economic development elements of RDPE (known as Axes 1 and 3).

The RDPE will be delivered through a number of activities including Small Capital Grant Schemes known as Rural Enterprise Grants (REG), Strategic Investment Grants (SIG) and Action Plans. REG and SIG are available for projects contributing to the four Action Plans:

A. Food and drink
B. Tourism
C. Environmental technologies
D. Support for the livestock industry

REGs are available to farmers and specific rural micro-businesses to the maximum value of £62,500 and 40% of total costs. The REG can fund small scale diversification and business development projects for the benefit of rural businesses.

SIGs are available for large scale and collaborative projects over the value of £62,500 or higher and 40% of total costs.

The RDPE funding currently available from AWM is primarily aimed at the treatment of agricultural wastes to reduce the amount of raw material being spread to land, provide improved management of these wastes, and to generate renewable energy largely for use on site. This may therefore limit the scale of an AD facility.

### 6.2.4 Local Enterprise Partnerships

Local enterprise partnerships (LEPs) will replace the regional development agencies and are locally-owned partnerships between local authorities and businesses. LEPs will play a central role in determining local economic priorities and undertaking activities to drive economic growth and the creation of local jobs. LEPs are based on meaningful economic areas and as such it is anticipated that they will be best placed to determine the needs of the local economy along and identify barriers to local economic growth. The 30 partnerships currently approved include the following LEPs covering the West Midlands area:

1. Birmingham and Solihull with East Staffordshire, Lichfield and Tamworth
2. Black Country
3. Coventry and Warwickshire
4. The Marches (Hereford, Shropshire and Telford)
5. Worcestershire

LEP’s will play a significant role in securing funding from the Regional Growth Fund (RGF). The RGF is a £1.4bn three year fund that will operate across England between 2011 and 2014 with the aim of stimulating sustainable economic growth and employment led by the private sector. The first round of applications to the RGF closed on 21st January 2011 and a total of 72 bids were received from the West Midlands. The second round of bidding is to be announced shortly and it is anticipated that there will be at least three rounds of bidding.

The Birmingham, Solihull, East Staffordshire, Lichfield and Tamworth LEP has been approved and covers a large proportion of the West Midlands area. The LEP support the planned national Green Deal and intend to develop a leading edge low carbon energy efficient economy. Birmingham has an agreed CO₂ emissions reduction target of 60% by 2026. This provides opportunities for low carbon and green technologies innovations and new "green" job and entrepreneurial opportunities. The LEP aim to establish ‘Green Funding’ mechanisms to support and deliver new partnership approaches to reduce the area's total energy bill of over £1.5 billion per annum. This could apply to AD with the generation of biomethane.

6.2.5 Green Investment Bank

The UK has a legal commitment to reduce its carbon emissions by 2050, and to generate a greater proportion of energy from renewable sources by 2020. The scale of investment needed is estimated to be between £200 billion and £1 trillion over the next 10-20 years. Traditional sources of capital for investment in green infrastructure can only provide £50 to £80 billion up to 2025, thus leaving a huge funding gap.

The Government have identified that a Green Investment Bank could be a means of gaining the private sector investment needed. This could in turn lead to the financial backing and security needed to develop biomethane facilities and increase the capacity for injection of biomethane to the grid.

The Government is currently considering and market testing options, and has stated that it will make an announcement on the business model for the Bank in May 2011. It expects the Bank to be operational in late 2012. It was announced in the Spending Review that the Government would capitalise the bank with £1 billion in 2013 – 2014 and in the budget announcements on the 25th March 2011 a further £2 billion of support was pledged.

A key question is whether the new body will be a 'bank' or a 'fund'. Setting up a Green Investment Bank able to raise its own finance is complicated by its potential classification in the National Accounts. If the Bank is classified as being within the public sector, then its borrowing will be included on the Government's balance sheet, thus working against measures to reduce the overall deficit. The decision of classification is based on the overall extent of government control over the Bank. In the budget announcements of March
2011 it was confirmed that the proposed Green bank should be able to borrow but not until 2015.

6.3 Shifting patterns and geography of demand
Within the West Midlands area there are several sectors which may have an increasing demand for gas in future years, or where the provision of biomethane may provide a viable solution to energy requirements.

Within many urban areas of the West Midlands solid wall housing is common. This includes terraced housing. With increased energy efficiency of domestic properties being a priority, a solution must be found for this type of housing where cavity wall insulation is not an option. The provision of renewable gas in the form of biomethane could be an option to decrease the carbon impact of heating this type of property.

In addition, as we move to a more computerised society the demand for energy to run data centres will increase and in many locations the electricity network may not be able to provide sufficient power. In these locations the use of biomethane to provide power via CHP, or the location of an AD facility in close proximity may provide a solution for the increasing energy needs.

Within the West Midlands many, often rural, areas are still not connected to the gas grid. In such areas agricultural farm based AD with a dedicated biomethane grid may be an option worthy of consideration. If oil based heating is currently used in these areas then the provision of renewable gas via biomethane is likely to be far more energy efficient.

6.4 Research and Development in AD
Research and Development (R&D) focused upon AD including biomethane production is supported in the UK in a number of ways.

6.4.1 Environment Transformation Fund
The Environmental Transformation Fund (ETF) is a financial commitment by the UK to address the challenge of climate change. It is divided into a UK and an international fund with the UK fund supporting the development and delivery of low carbon energy technology. The ETF began operation in April 2008.

Around £10m funding from the ETF was allocated to the Anaerobic Digestion Demonstration Programme (ADDP). The ADDP is being delivered through capital grants administered by WRAP with assistance from the Carbon Trust. Each successful project will demonstrate how the innovative use of AD technology can make a significant contribution to achieving a number of cross cutting aims. The following five preferred bidders were announced on 8 June 2009:

- Blackmore Vale Dairy
- GWE Biogas
- Langage Farm
- Staples Vegetables
• United Utilities & National Grid

The ADDP will provide a significant opportunity for R&D into AD and the use of biogas.

6.4.2 Anaerobic Digestion Development Centre

The Anaerobic Digestion Development Centre (ADDC) in Redcar, North Yorkshire, is operated by the Centre for Process Innovation (CPI) to help the development of new and improved AD processes. The previous Labour government agreed to develop the facility in March 2010 as part of its AD implementation plan and the facility was granted £1 million from the Department for Energy and Climate Change (DECC).

The ADDC can process a range of organic wastes in single or mixed streams and has adaptable pre-treatment, digestion and post-treatment technologies. The process includes a pasteurisation unit to meet ABPR regulations and to meet PAS110 standards for digestate, and is able to operate under mesophilic or thermophilic conditions.

The facility will allow organisation to configure and test various AD processes with the aims of:

• Reducing the size and cost of AD installations
• Increasing the yield of methane from all feedstocks
• Developing pre- and post-treatment technologies to improve yields
• Enhancing the properties of digestate to develop high quality natural fertilisers
• Improving effluent water quality
• Developing purification and monitoring processes to allow the injection of biogas into the gas grid

6.4.3 Technology Strategy Board

The Technology Strategy Board (TSB) has a budget for 2008-2011 of £711m along with funding from the Regional Development Agencies of £180m and at least £120m from the Research Councils.

In May 2008 the TSB published their Strategic Plan which outlined their focus for the funding period as well as providing a longer term perspective.

The Strategic Plan identified a number of application areas and key technology areas. Application areas currently include energy generation and supply and environmental sustainability, which includes developing activity in resource and energy efficiency, and waste and pollution management.

The TSB encourages innovation through the organisation and sponsorship of various competition programmes. Some such competitions will ultimately provide valuable information applicable to the treatment of waste via AD and the production of biomethane, such as the current competition aiming to
develop methods to accurately measure the energy output from the bio-based fraction of mixed waste on a basis acceptable to Ofgem.

6.5 Strategy for next gas distribution price control – RIIO-GD1

It is evident that the issues surrounding injection of biomethane to the gas grid are at the forefront in the development of future policy and pricing controls.

The next gas distribution price control (RIIO-GD1)\(^{30}\) will set the outputs that the eight gas distribution networks (GDNs) need to deliver for their consumers and the associated revenues they are allowed to collect between the 1\(^{st}\) April 2013 and the 31\(^{st}\) March 2021.

A consultation document issued by Ofgem recently set out the key elements that the network companies need to understand in order to develop their business plans. It states that biomethane could play a significant role in meeting the UK’s carbon emissions targets and as such issues surrounding the injection of biomethane to the grid included:

- Encouragement of the GDN’s to connect new biomethane plants to the grid in a timely and efficient manner and to provide timely and accessible information to potential connectees
- Proposals to introduce connection standards for biomethane to reflect the specific needs of this customer group
- Inviting stakeholders’ views on whether there are any wider network or other benefits from biomethane that should be reflected in the current connection and use of system charging arrangements
- Proposals to require companies to report on the capacity of biomethane connected to the network but no financial rewards/penalties in respect of performance given that the development of biomethane will be influenced by factors outside the companies’ control (e.g. financial support from the Renewable Heat Incentive)

6.6 Using gas as an energy carrier

One option for biogas utilisation is to use the gas as an ‘energy carrier’ through the gas grid, with the production of electricity at the point of consumption.

There does not appear to be any direct reference to the above issue in the Energy Bill 2011. However the principal objectives of DECC are stated as:

- Tackling barriers to investment in energy efficiency
- Enhancing energy security
- Enabling investment in low carbon energy supplies

\(^{30}\) http://www.ofgem.gov.uk/NETWORKS/GASDISTR/RIIO-GD1/Pages/RIIO-GD1.aspx
It could be argued that following attributes of biomethane injection to the gas would lend it well to being supported according to the above objectives:

- The production of biomethane from renewable resources generated in the UK (including municipal and C&I waste, and agricultural products and waste)
- Efficiency of energy transportation with minimal losses via the gas grid to the point of consumption
- Efficient end use of biogas either via CHP generation or in gas boilers

DECC have indicated in their Annual Energy Statement of 27th July 2010\(^\text{31}\) that there is a need to move towards electrification of much of the UK’s heating, industry and transport, along with cleaner generation. In the Annual Energy Statement DECC point out that:

“We cannot rely on gas or oil for our heating needs indefinitely”.

They go on to state that their 2050 Pathways work has identified that:

“Future heat supply will need to involve some combination or electrification (through heat pumps for example) and the use of bio-gas, bio material and other renewable heat technologies. In some cases these will be delivered via local community level heat networks using co-generation of heat and power (CHP)”.

However, it is unclear whether DECC have a preference for using biomethane as an energy carrier via the gas grid to a point where it could generate electricity (and heat) close to the point of consumption, or whether they would prefer to generate electricity at the AD facility for connection to the electricity grid and/or to locate the AD facility close to the point of consumption. In considering which are the best options from a perspective of energy use, carbon consumption, economic cost, and technical and regulatory impacts, there are a wide range of issues which need to be considered including but not limited to:

- Transmission issues associated with electricity and heat versus conveyance of gas
- Practical issues regarding the capacity of the electricity and gas grids in the short, medium and long term
- Reliability of the demand for electricity and heat throughout a year and over the planned lifespan of the facility

All of these issues could be site specific.

## 7 Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption</td>
<td>A process in which one substance permeates another</td>
</tr>
<tr>
<td>AD (Anaerobic Digestion)</td>
<td>A natural biological process carried out by bacteria in the absence of air, by which organic material is broken down into a digestate and biogas</td>
</tr>
<tr>
<td>ADBA (Anaerobic Digestion and Biogas Association)</td>
<td>Established to represent businesses involved in the AD and biogas industries, to help remove barriers and grow businesses. Its principal aim is to enable and facilitate the development of a mature AD industry in the UK within 10 years</td>
</tr>
<tr>
<td>Adsorption</td>
<td>The accumulation of molecules of a gas to form a thin film on the surface of a solid</td>
</tr>
<tr>
<td>AWM (Advantage West Midlands)</td>
<td>The regional development agency for the West Midlands. In March 2012 it will close and economic development and social and physical regeneration will be led by Local Enterprise Partnerships (LEPs) and other successor bodies</td>
</tr>
<tr>
<td>Aerobic composting</td>
<td>The aerobic stabilisation of organic material (including digestate) for example by mechanical turning (windrowing) or by static pile aeration</td>
</tr>
<tr>
<td>AH (Animal Health)</td>
<td>Executive Agency of DEFRA operating across Great Britain on behalf of the Scottish Government, the Welsh Assembly Government and the Food Standards Agency, as well as DEFRA. Working to prevent, control and eradicate exotic and endemic notifiable diseases, minimise the economic impact of animal disease, ensure high standards of welfare in farmed animals and improve food safety</td>
</tr>
<tr>
<td>AQMA (Air Quality Management Area)</td>
<td>Within the meaning of the Environment Act 1995 which has been designated due to concerns about oxides of nitrogen</td>
</tr>
<tr>
<td>Biogas</td>
<td>A combustible gas created by anaerobic digestion of organic material and composed of approximately 60% methane, 40% carbon dioxide and some trace elements</td>
</tr>
<tr>
<td>Biomethane</td>
<td>A gas mixture that is predominantly methane (&gt;97%) and is sourced from organic material</td>
</tr>
<tr>
<td>BMW (Biodegradable Municipal Waste)</td>
<td>The biodegradable component of municipal solid waste (see definition below)</td>
</tr>
<tr>
<td>Calorific value</td>
<td>The amount of heat released during the combustion of a specified amount of gas, measured in units of energy per unit of gas</td>
</tr>
<tr>
<td>Catering waste</td>
<td>Catering waste is any waste food collected from commercial premises or households. Some catering waste is controlled by the ABPR</td>
</tr>
<tr>
<td><strong>C:N ratio (Carbon to Nitrogen Ratio)</strong></td>
<td>Ratio of the mass of carbon to the mass of nitrogen in a substance</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td><strong>CHP (Combined Heat and Power)</strong></td>
<td>The use of a heat engine or a power station to generate simultaneously both electricity and useful heat</td>
</tr>
<tr>
<td><strong>CLO (Compost-like output)</strong></td>
<td>The output produced when mixed municipal solid waste is biologically treated in mechanical biological treatment plants or autoclaves. It can be landfilled and has the benefit of lower greenhouse gas emissions compared to untreated waste</td>
</tr>
<tr>
<td><strong>DCLG (Department for Communities and Local Government)</strong></td>
<td>The Department sets policy on supporting local government; communities and neighbourhoods; regeneration; housing; planning, building and the environment; and fire</td>
</tr>
<tr>
<td><strong>DECC (Department for Energy and Climate Change)</strong></td>
<td>DECC was formed in 2008 from the Energy Division of BERR and parts of DEFRA</td>
</tr>
<tr>
<td><strong>DEFRA (Department for Environment, Food and Rural Affairs)</strong></td>
<td>Government department working in England making policy and legislation in area such as the natural environment, biodiversity, plants and animals, sustainable development and the green economy, food, farming and fisheries, animal health and welfare, environmental protection and pollution control, rural communities and issues</td>
</tr>
<tr>
<td><strong>Dew point</strong></td>
<td>The dew point is the temperature to which a given parcel of air must be cooled, at constant barometric pressure, for water vapour to condense into water</td>
</tr>
<tr>
<td><strong>Digestate</strong></td>
<td>The liquid slurry left after the anaerobic digestion process. Digestate can be used straight from the digester, in which case it is called whole digestate. Alternatively it can be separated into liquor and fibre</td>
</tr>
<tr>
<td><strong>EA (Environment Agency)</strong></td>
<td>An executive non-departmental public body responsible to DEFRA with the aims of protecting and improving the environment, and promoting sustainable development</td>
</tr>
<tr>
<td><strong>EEA (East of England Development Agency)</strong></td>
<td>The regional development agency for the East of England</td>
</tr>
<tr>
<td><strong>EPR (Environmental Permitting Regulations)</strong></td>
<td>The Environmental Permitting Regulations (England and Wales) 2010 were introduced on 6 April 2010, replacing the 2007 Regulations which established a common permitting programme for Waste and Pollution Prevention and Control (PPC) regimes</td>
</tr>
<tr>
<td><strong>ERDF (European Regional Development Fund)</strong></td>
<td>Managed by DCLG and focused on reducing economic disparities within and between member states by supporting economic regeneration and safeguarding jobs. Funding is targeted to meet three objectives set down by the European Commission: convergence, regional competitiveness, and European territorial co-operation</td>
</tr>
<tr>
<td><strong>European Site</strong></td>
<td>Candidate or Special Area of Conservation, and proposed or Special Protection Area in England and Wales, within the meaning of Council Directives 79/409/EEC, 92/43/EEC and the Conservation (Natural Habitats &amp;c.) Regulations 1994</td>
</tr>
<tr>
<td><strong>FDF (Food and Drink Federation)</strong></td>
<td>Membership organisation that represents and advises UK food</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Fit (Feed in Tariff)</td>
<td>A payment made to generators of small scale renewable electricity generation for electricity produced</td>
</tr>
<tr>
<td>Gas Safety (Management) Regulations</td>
<td>The Gas Safety (Management) Regulations 1996 (SI 1996 No.551) deal with the management of the safe flow of gas through Great Britain’s natural gas networks. The key objective is to ensure safety, by ensuring security of supply (especially to domestic consumers), and by ensuring the safety standards of emergency services provided by the gas industry</td>
</tr>
<tr>
<td>GDN (Grid Distribution Network)</td>
<td>One of the 8 regional gas distribution networks in Great Britain. These consist of low pressure pipe-lines which offtake gas from the high-pressure, long-distance National Transmission System, and convey it to the end-consumer or to the pipes of an “IGT”</td>
</tr>
<tr>
<td>GIS (Geographical Information System)</td>
<td>A system that captures, stores, analyses, manages, and presents data with reference to geographic location data</td>
</tr>
<tr>
<td>GHG (Greenhouse Gas)</td>
<td>Gases in an atmosphere that absorb and emit radiation within the thermal infrared range</td>
</tr>
<tr>
<td>H-gas</td>
<td>High calorie gas (Germany)</td>
</tr>
<tr>
<td>HACCP (Hazard Analysis and Critical Control Point)</td>
<td>In the context of PAS110, a system used for the identification, evaluation and control of hazards which are significant for the production of digested materials that can be used without harm</td>
</tr>
<tr>
<td>HSE (Health and Safety Executive)</td>
<td>National independent regulator for work related health, safety and illness</td>
</tr>
</tbody>
</table>
| ICF (Incomplete combustion factor) | \[
\text{ICF} = \frac{WN - 50.73 + 0.03PN}{1.56}
\]
Where:
WN = Wobbe Number
PN = sum of the percentages by volume of propane and nitrogen in the equivalent mixture |
<p>| iGT (Independent Gas Transporter) | A licensed Gas Transporter other than National Grid Gas and the operators of the 8 Gas Distribution Networks |
| kW_e | Electrical power output in kilowatts |
| kW_th | Thermal power output in kilowatts |
| L-gas | Low calorie gas (Germany) |
| LATS (Landfill Allowance Trading Scheme) | An initiative by the UK government to help reduce the amount of biodegradable municipal waste (BMW) sent to landfill. It provides the legal framework for the scheme and for the allocation of tradable landfill allowances to each waste disposal authority in England. These allowances will convey the right for a waste disposal authority to landfill a certain amount of biodegradable municipal waste in a specified scheme year |
| Lignocellulose | A complex network of lignin, cellulose and hemicellulose found in plants |</p>
<table>
<thead>
<tr>
<th><strong>LNG (Liquefied Natural Gas)</strong></th>
<th>Gas stored and / or transported in liquid form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LTS (Local Transmission Systems)</strong></td>
<td>A pipeline system operating at &gt;7bar that transports gas from NTS offtakes to distribution systems. Some large users may take their gas direct from the LTS</td>
</tr>
<tr>
<td><strong>MBT (Mechanical and Biological Treatment)</strong></td>
<td>Waste processing facility that combines sorting with a form of biological treatment such as composting or anaerobic digestion</td>
</tr>
<tr>
<td><strong>Mercaptan Sulphur</strong></td>
<td>Organic compound containing sulphur. The term mercaptan is derived from the Latin mercurium captans (capturing mercury)</td>
</tr>
<tr>
<td><strong>Mesophilic digestion</strong></td>
<td>The biological process that occurs when an Anaerobic Digester is heated to 25-35°C</td>
</tr>
<tr>
<td><strong>MRF (Materials Recycling Facility)</strong></td>
<td>Recyclables are taken to MRFs to be separated, sorted and sent onwards for reprocessing and recycling</td>
</tr>
<tr>
<td><strong>MSW (Municipal Solid Waste)</strong></td>
<td>Municipal waste is that which comes under the control of the Local Authority and includes household waste and other wastes collected by a waste collection authority or its agents, such as municipal parks and gardens waste, beach cleansing waste, commercial or industrial waste, and waste resulting from the clearance of fly-tipped materials</td>
</tr>
<tr>
<td><strong>NPV (Net Present Value)</strong></td>
<td>An economic standard method for evaluating competing long-term projects in capital budgeting</td>
</tr>
<tr>
<td><strong>NNFCC (National Non Food Crop Centre)</strong></td>
<td>Organisation supplying information to industry, farmers, academia and government</td>
</tr>
<tr>
<td><strong>NTS (National Transmission System)</strong></td>
<td>A high-pressure system consisting of terminals, compressor stations, pipeline systems and offtakes. Designed to operate at pressures up to 85 bar. NTS pipelines transport gas from terminals to NTS offtakes</td>
</tr>
<tr>
<td><strong>OECD ( Organisation for Economic Co-operation and Development)</strong></td>
<td>Organisation consisting of 34 member countries established in 1961 with the aim of promoting policies that will improve the economics and social well-being of people around the world</td>
</tr>
<tr>
<td><strong>OFGEM (Office of Gas and Electricity Markets)</strong></td>
<td>The regulatory agency responsible for regulating Great Britain’s gas and electricity markets</td>
</tr>
<tr>
<td><strong>OFT (Office of Fair Trading)</strong></td>
<td>A non-ministerial government department established by statute in 1973. The OFT is the UK's consumer and competition authority</td>
</tr>
<tr>
<td><strong>OfWAT (Office of Water Services)</strong></td>
<td>Economic regulator of water and sewerage sectors in England and Wales</td>
</tr>
<tr>
<td><strong>PAS110 (Publicly available specification)</strong></td>
<td>The UK’s standard for ensuring digestate produced from anaerobic digestion meets market needs and protects the environment</td>
</tr>
<tr>
<td><strong>QMS (Quality management system)</strong></td>
<td>Management system to direct and control an organisation with regard to quality. In the context of AD it is a system for planning, achieving and demonstrating effective control of all operations and associated quality management activities necessary to achieve digested materials that are fit for</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>QP (Quality protocol)</td>
<td>Set of criteria for the production, placement on the market, storage and use of products derived from suitable types and sources of waste, such that any risks to the environment and to human and animal health are acceptably low when any such product may, under certain circumstances, be used without waste regulatory controls, in those countries in which the QP applies.</td>
</tr>
<tr>
<td>Ramsar Site</td>
<td>Ramsar sites are wetlands of international importance, designated under the Ramsar Convention signed in 1971, which provides for the conservation and good use of wetlands. The UK Government ratified the Convention and designated the first Ramsar sites in 1976.</td>
</tr>
<tr>
<td>RDF (Refuse derived fuel)</td>
<td>Segregated high calorific fraction of processed MSW</td>
</tr>
<tr>
<td>RGGO (Renewable Gas Guarantee of Origin)</td>
<td>Unique identifier used to label biomethane injected to the grid containing information about where, when and how it was produced</td>
</tr>
<tr>
<td>ROC (Renewables Obligation Certificate)</td>
<td>Administered by Ofgem. Awarded to owners of renewable projects for renewably generated electricity. Large electricity generators are required to have a minimum amount of electricity generated from renewable generation, any less and ROCs have to be bought to cover the shortfall, any excess can be sold via ROCs.</td>
</tr>
<tr>
<td>SI (Soot Index)</td>
<td>[SI = 0.896 \tan^{-1} (0.0255C_2H_6 - 0.0233N_2 + 0.617)]</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>Any chemical compound composed of units of the form R₂SiO₉, where R is a hydrogen atom or a hydrocarbon group</td>
</tr>
<tr>
<td>SSSI (Site of Special Scientific Interest)</td>
<td>Within the meaning of the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000)</td>
</tr>
<tr>
<td>Thermophilic digestion</td>
<td>The biological process that occurs when an Anaerobic Digester is heated to 50-60°C</td>
</tr>
<tr>
<td>UKAS (United Kingdom Accreditation Service)</td>
<td>National accreditation body recognised by government to assess organisations that provide certification, testing, inspection and calibration services. against internationally agreed standards</td>
</tr>
<tr>
<td>Wobbe Number (Wobbe Index)</td>
<td>[WN = \frac{\text{calorific value}}{\sqrt{\text{relative density}}}]</td>
</tr>
<tr>
<td>WRAP (Waste and Resources Action Programme)</td>
<td>A government agency working to reducing waste, develop sustainable products and use resources in an efficient way</td>
</tr>
</tbody>
</table>
8 Appendix I: European Quality Standards for Biomethane

The upgrading of biogas to the quality of natural gas and its injection into gas grid has become increasingly important in recent years as this process enables efficient use of biomethane. Injection of biomethane allows for both the spatial and temporal separation between demand and supply, whilst also enabling efficient energy use at heat sinks. Plants which utilise the biogas in internal CHPs generally only have limited capacity for this efficient use of energy. Upgrading to biomethane increases the possibilities for the use of biogas, because in addition to burning and the production of electricity it is also possible to use it as fuel.

Both quality and technical requirements need to be met for the injection of biomethane to the natural gas grid. Nation specific regulations on the quality requirements generally only provide minimum standards, which may be adjusted by the gas grid providers to meet their own requirements. The technical requirements are a consequence of the planned injection point and the intake capacity of the grid.

The injection of biomethane mostly occurs as exchange gas, and so the injected biomethane and the natural gas should have the same calorific values. Therefore it is necessary to increase the calorific value and to adjust the Wobbe Index depending on the natural gas quality. In addition, an adjustment of the concentrations of materials such as water, oxygen and hydrogen to the grid requirements is needed. The dew point of the injected biomethane has to be lower than the soil temperature during fuel-line pressure into the gas grid to ensure that condensation of liquid is avoided.

During the planning process local requirements of injection at the plant location are confirmed. The gas grid providers therefore generally reserve the right to inspect the technical injection requirements and to determine an appropriate injection location. The transport and distribution grids have differing pressure ratings. Low pressure natural gas grids have a pressure of less than 100 mbar, whilst the pressure in medium pressure natural gas grids can be up to 1 bar with pressure in high pressure natural gas grids potentially being substantially higher. It is therefore vital to adjust the pressure of the biomethane to the fuel-line (gas-line) pressure in the respective natural gas grid.

The intake capacity of the natural gas grid at the designated injection point also needs to be considered. The amount of biomethane cannot surpass the intake capacity of the grids, which can create problems with injection in regional grids characterised by low gas usage, especially during the summer months which are already characterised by low demand. In this case injection may not be possible at the desired injection point or may be possible only with increased technical effort.

Within the European Union no common standards exist regarding the injection of biomethane into existing natural gas grids. In the Directive 2003/55/EC of the European Parliament and the Council of 26 June 2003 concerning...
common rules for the common market in natural gas and repealing directive 98/30/EC" biomethane is referred to as follows:

“Member States should ensure that, taking into account the necessary quality requirements, biogas and gas from biomass or other types of gas are granted non-discriminatory access to the gas system, provided such access is permanently compatible with the relevant technical rules and safety standards. These rules and standards should ensure that these gases can technically and safely be injected into and transported through the natural gas system and should also address the chemical characteristics of these gases”

However, quality standards on the injection of biomethane already exist in several member states, which are described below.

**Germany**

In Germany the conditions for biomethane injection to the gas grid are regulated in the framework of the “Gasnetzzugangsverordnung” (gas grid inflow decree – GasNVZ). In particular this covers an agreement on free grid access for biomethane producers, the regulation of the cost coverage of the grid connection, and the fee for the transport fuel customers, as well as the quality standards for the injected biomethane.

According to the decree, the injected biomethane must comply with the standards stipulated in the working papers 260 and 262 by the DVGW (German Association of the Gas and Water industry).

<table>
<thead>
<tr>
<th>Unit</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value kWh/Nm³</td>
<td>8.4 – 13.1</td>
</tr>
<tr>
<td>Wobbe Index kWh/Nm³</td>
<td>10.5 – 15.7</td>
</tr>
<tr>
<td>Methane content %</td>
<td>Depends on calorific value</td>
</tr>
<tr>
<td>CO₂ content %</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>O₂ content %</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>H₂ content %</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>H₂S content mg/Nm³</td>
<td>&lt; 5.0</td>
</tr>
<tr>
<td>Sulphur content mg/Nm³</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>Relative density</td>
<td>0.58 – 0.65</td>
</tr>
</tbody>
</table>

Table 9: Required standards of biomethane quality in Germany

The dew point is determined by the gas grid provider. The oxygen concentration depends upon whether injection takes place into a dry (3% oxygen content) or wet (0.5% oxygen content) natural gas grid. The methane content depends upon the quality of the natural gas, for example in an L-gas (low calorific value) grid a concentration of 90% can be sufficient whilst in an H-gas (high calorific) grid even a concentration of 100% would be insufficient to sustain the calorific value.

**The Netherlands**

The gas quality required for the injection into the gas grid is established by the Dutch Gas Legislation of 22 November 2006. Several parameters have been summarised in the Table 10:
An introduction to the production of biomethane gas and injection to the national grid
Revised Final Report

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value</td>
<td>31.6 – 38.7</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>43.46 – 44.41</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
</tr>
<tr>
<td>Methane content</td>
<td>Mol %</td>
</tr>
<tr>
<td>Dew Point (pressure 8 bar)</td>
<td>°C</td>
</tr>
<tr>
<td>Aromatics (THT)</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>Mercaptan sulphur</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>H₂S content</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>CO₂ content (dry grid)</td>
<td>Mol %</td>
</tr>
<tr>
<td>CO content</td>
<td>Mol %</td>
</tr>
<tr>
<td>O₂ content (dry grid)</td>
<td>Mol %</td>
</tr>
<tr>
<td>H₂ content</td>
<td>Mol %</td>
</tr>
<tr>
<td>Benzol, Toluol, Xylol</td>
<td>Ppm</td>
</tr>
<tr>
<td>Aromatic Hydrocarbons</td>
<td>Mol %</td>
</tr>
<tr>
<td>Dust</td>
<td>Technically free</td>
</tr>
<tr>
<td>Siloxanes</td>
<td>Ppm</td>
</tr>
</tbody>
</table>

**Table 10: Required standards of biomethane quality in The Netherlands (Source: ISET E.V.)**

**Luxembourg**

In the Grand Duchy of Luxembourg no quality standards for biomethane are legally defined. The operators of the plants currently in operation injecting biomethane into the natural gas grid make use of the specifications of the German DVGW working paper G260 and G262 as well as the quality of the natural gas in the existing grid.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value</td>
<td>11-12</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>14-15</td>
</tr>
<tr>
<td>Methane content</td>
<td>85.5 – 95.0</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>CO₂ content</td>
<td>&lt; 6</td>
</tr>
<tr>
<td>O₂ content</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>H₂ content</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>H₂S content</td>
<td>&lt; 5.0</td>
</tr>
<tr>
<td>Dew Point</td>
<td>-8°C at 70 bar</td>
</tr>
<tr>
<td>Relative density</td>
<td>0.58 – 0.65</td>
</tr>
</tbody>
</table>

**Table 11: Standards of biomethane quality in Luxembourg (Project Minett-Compost)**

**Sweden**

The gas grid is not widely developed in Sweden and as a result biomethane is mainly used as a transport fuel. The quality requirement standards in place are those of the 1999 SS 155438 (Motorbränslen – Biogas som bränsle till snabbgående ottomotorer) developed for transport fuel use.

This also serves as the standard for the injection of biomethane into the Swedish gas grid, with all additional requirements agreed directly between the gas producer and the operators of the gas grid. This concerns in particular the calorific adjustment which is not covered by SS 155438. National regulations
regarding biomethane upgrading and its injection into the grid are currently being developed.

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Biomethane Type A</th>
<th>Biomethane Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value</td>
<td>kWh/Nm³</td>
<td>Adjustment to the regional natural gas grid</td>
<td>Adjustment to the regional natural gas grid</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>MJ/Nm³</td>
<td>47.4 – 46.4</td>
<td>43.9 – 47.3</td>
</tr>
<tr>
<td>Methane content</td>
<td>Vol. %</td>
<td>96 – 98</td>
<td>96 – 99</td>
</tr>
<tr>
<td>Total sulphur</td>
<td>mg/Nm³</td>
<td>&lt; 23</td>
<td>&lt; 23</td>
</tr>
<tr>
<td>Sum of CO₂ - O₂ - N₂ content</td>
<td>%</td>
<td>&lt; 4</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Out of this O₂ content</td>
<td>%</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Nitrogen Compound, Maximum (without N₂, calculated as NH₃)</td>
<td>mg/Nm³</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Water content</td>
<td>mg/Nm³</td>
<td>&lt; 32</td>
<td>&lt; 32</td>
</tr>
<tr>
<td>Water Dew Point on Highest Bearing Pressure (t=lowest daily average temperature on monthly basis)</td>
<td>°C</td>
<td>-5</td>
<td>-5</td>
</tr>
<tr>
<td>Relative density</td>
<td></td>
<td>0.58 – 0.65</td>
<td></td>
</tr>
<tr>
<td>Dimension of Particles</td>
<td>Mm</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

Table 12: Required standards of biomethane quality in Sweden

Austria
The specifications of the “Gaswirtschaftsgesetz” (gas industry legislation) are applied for the injection of biomethane into the gas grid. This generally obliges gas grid providers to connect producers of biomethane to their grid, as long as the gas complies with guidelines G31 and G33 set by the ÖVGW (Austrian Association for the Gas and Water Industry).

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value</td>
<td>kWh/Nm³</td>
</tr>
<tr>
<td>Wobbe Index</td>
<td>kWh/Nm³</td>
</tr>
<tr>
<td>Relative density</td>
<td>Mol %</td>
</tr>
<tr>
<td>Methane content</td>
<td>Mol %</td>
</tr>
<tr>
<td>Dew Point Water (pressure 40 Bar)</td>
<td>°C</td>
</tr>
<tr>
<td>Dew Point Hydrocarbons (at operating pressure)</td>
<td>°C</td>
</tr>
<tr>
<td>Sulphur content</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>Mercaptan sulphur</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>H₂S content</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>Carbonyl Sulphide (COS) content</td>
<td>mg/Nm³</td>
</tr>
<tr>
<td>CO₂ content</td>
<td>Vol %</td>
</tr>
</tbody>
</table>

32 Biomethane Type A is for cars with controlled catalytic converter
33 Biomethane Type B is for cars without a catalytic converter
34 Differing methane content is permitted as long as all other parameters of the ÖVGW are complied with and a calorific value of at least 10.7 kWh m³ is achieved. Biomethane from depots and clarification plants cannot be used.
An introduction to the production of biomethane gas and injection to the national grid
Revised Final Report

ORGANIC RESOURCE AGENCY LTD

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O₂ content</strong></td>
<td>Vol %</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td><strong>H₂ content</strong></td>
<td>Vol %</td>
<td>&lt; 4</td>
</tr>
<tr>
<td><strong>N₂ content</strong></td>
<td>Vol %</td>
<td>&lt; 5</td>
</tr>
<tr>
<td><strong>Ammonia</strong></td>
<td></td>
<td>Technical free</td>
</tr>
<tr>
<td><strong>Fixed and fluid elements</strong></td>
<td></td>
<td>Technical free</td>
</tr>
<tr>
<td><strong>Halogen compounds</strong></td>
<td>mg/Nm³</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total silicon (siloxanes, silanes)</strong></td>
<td>mg/Nm³</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 13: Required standards of biomethane quality in Austria

France
The injection of biomethane into the natural gas grid is currently not permitted in France. In the framework of a project in Montech, in the Tarn-et-Garonne department, upgraded landfill gas was previously being injected. However, concerns over the gas quality and possible contamination of the gas grid have led to the cessation of gas injection.

The “L’Agence Française de Sécurité Sanitaire de l’Environnement et du Travail” spoke out in favour of the injection of biomethane into the natural gas grid in October 2008 in order to improve energy use efficiency. According to Gaz de France-Suez, the final decision on the admissibility of the grid injection of biomethane is still outstanding. Current access requirements into the grid of Gaz de France-Suez and that of the transport operator GRT already allow for the possible injection of biomethane.
9 Appendix II: European reference projects

The countries with the longest-standing experience in the upgrading of biomethane are The Netherlands, Sweden and Switzerland. Whilst Sweden has the greatest number of plants upgrading biogas to biomethane, Germany has the greatest injection capacity. Amongst other factors this is a result of the already existing gas grid structure. A significant increase in biogas upgrading plants in Germany is seen from 2006 onwards. Table 14 provides information on the overall injection capacity of plants in Europe in which injection projects are operational (as of November 2010).

<table>
<thead>
<tr>
<th>Country</th>
<th>Biomethane injection capacity (Nm$^3$/per hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>31,850</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>2,920</td>
</tr>
<tr>
<td>Sweden</td>
<td>2,610</td>
</tr>
<tr>
<td>Switzerland</td>
<td>960</td>
</tr>
<tr>
<td>Austria</td>
<td>630</td>
</tr>
<tr>
<td>Norway</td>
<td>270</td>
</tr>
<tr>
<td>UK</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 14: European injection capacity (Sources: dena, ISET e.V., DVGW e.V., IEA)

Germany

In the Gas Network Access Ordinance effective from April 2008 the following biomethane injection targets are defined:

1. By 2020 60 billion kWh biomethane fed into the gas grid each year
2. By 2030 100 billion kWh biomethane fed into the gas grid each year.

According to the current planning department, around 60 plants with an hourly injection rate of about 40,000 cubic metres of biomethane are currently linked to the German grid (DENA, November 2010).

As a result of economic drivers by way of feed in tariffs defined in the Renewable Energy Sources Act (EEG) the injected biomethane is largely used to generate electricity with usage of the waste heat in the framework of cogeneration by block and heat power plants. This means that the biomethane is normally not directly marketed to grid providers, but that the grid is only used as a means of transport for the later removal of the gas at different locations. The reason for this is the fact that the financial incentives within the EEG towards the use of waste heat are more lucrative than the direct marketing of the gas for heat use etc. The feed-in tariffs are guaranteed from the beginning of the year in which operations start and for the following 20 years according to a fixed rate.

The Gas Network Access Ordinance (GasNZV) requires grid operators on all pressure levels to grant preferred grid access to biomethane plants which have put in a request. Grid access costs are split equally between the grid operator and the biomethane supplier. In addition grid operators are to grant preference to biomethane transport clients when it comes to concluding entry...
and exit contracts, as long as these gases are compatible with the grid. The feed-in of biogas cannot be denied by the grid operator on the basis of an existing capacity shortage.

The Market Incentive Program was one of the German Government’s funding mechanisms to support the production of heat with renewable energies and was available until December 2010. Funding amounted to €400 million and was available for biogas conditioning plants and biogas pipelines for unconditioned biogas (micro gas grids). Biogas upgrading plants up to a capacity of 350 Nm$^3$/h were entitled to a grant of up to 30% towards investment costs and biogas pipelines for unconditioned biogas could be supported if the biogas transported is applied in a cogeneration process or conditioned to reach natural gas quality.

The vast majority of German biomethane plants are based on the fermentation of energy crops such as sweetcorn, rye and barley but also utilise pig and cattle slurry. In order to meet renewable energy targets for biomethane production it is estimated that roughly 1.2 million hectares of cultivable land be made available for the development of biomass for biogas by 2020. Biogas plants using garden waste as their input feedstock are still rare in Germany compared with other European countries.

Amongst the various upgrading technologies, pressure swing adsorption (PSA) and chemical scrubbing currently prevail in Germany. The number of plants utilising different treatment technologies is shown in Table 15.

<table>
<thead>
<tr>
<th>Upgrading process</th>
<th>Number of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Swing Adsorption (PSA)</td>
<td>14</td>
</tr>
<tr>
<td>Chemical scrubbing</td>
<td>14</td>
</tr>
<tr>
<td>Water scrubbing</td>
<td>9</td>
</tr>
<tr>
<td>Membrane separation</td>
<td>1</td>
</tr>
<tr>
<td>No information provided</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 15: Upgrading processes used in Germany (Source: Deutsche Energie-Agentur GmbH (dena), November 2010)
Homberg-Efze Facility

Figure 17: Homberg Efze biomethane facility

The biogas plant in Homberg-Efze is situated in the north of the German state of Hessen. The plant was installed by the firm Biogas Homberg GmbH and Co. KG, which was especially founded for its construction.

The shareholders of the company are the public utility company of Kassel as well as the county farmers’ association and its machinery association (Verein and GmbH), the MSG Mandat accountancy association and 30 farmers from the region.

<table>
<thead>
<tr>
<th>Capacity</th>
<th>36,500 tpa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstocks</td>
<td>Maize silage (24,000 tpa) Grass silage (1,500 tpa) Slurry (11,000 tpa)</td>
</tr>
<tr>
<td>Digestion technology</td>
<td>Fully mixed wet digestion</td>
</tr>
<tr>
<td>Upgrading technology</td>
<td>Pressurised water scrubbing (by Malmberg Water)</td>
</tr>
<tr>
<td>Biogas production</td>
<td>Ca. 720 Nm$^3$</td>
</tr>
<tr>
<td>Biomethane production</td>
<td>Ca. 350 Nm$^3$</td>
</tr>
<tr>
<td>Biomethane injection (Transport)</td>
<td>Public Grid E.On Mitte AG</td>
</tr>
<tr>
<td>Gas purchases</td>
<td>Städtische Werke AG Kassel (public utility companies)</td>
</tr>
<tr>
<td>CHP Power</td>
<td>185 kW electrical, 223 kW thermal</td>
</tr>
<tr>
<td>Construction time</td>
<td>1 year</td>
</tr>
<tr>
<td>Start of operation</td>
<td>May 2009</td>
</tr>
</tbody>
</table>

Table 16: Details of Homberg-Efze biomethane injection facility

Biogas with a methane content of around 52% is compressed to about 8 bar and then cooled with water via a cooling system. After cooling, the carbon dioxide and hydrogen sulphide are separated in a scrubber tower. The tower contains support media to enable efficient circulation of the water.
Water is injected into the top of the tower, the biogas flows from the bottom of the tower in a counter current process to the top. Carbon dioxide and hydrogen sulphide are absorbed by the water. The gas exiting at the top of the tower has a methane content of > 96% as long as the proportion of inert gasses is low.

The liquid used for absorption contains gasses in solution, amongst these also a low methane component. The water pressure is therefore lowered to 2 bar in a flash tank. The extracted gas contains methane, which is returned into the gas upgrading plant.

The water which is loaded with carbon dioxide runs through the desorption plant from the bottom to the top. Carbon dioxide and hydrogen sulphide are extracted and the upgraded water can be reused.

After the absorption tower the purified gas is dried and conditioned for injection, i.e. undergoes compression up to 16 bar, addition of propane and subsequent odorisation.

To provide heat for the biological part of the AD process and conversion to electricity production, part of the biomethane is used parasitically on the plant’s block CHP plant. The local grid provider (E.ON Mitte AG) specifies the following minimum requirements on the biomethane that is to be injected as shown in Table 17:

<table>
<thead>
<tr>
<th>Wobbe Index</th>
<th>13.6 - 15.7 kWh/m³ (H-Gas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher calorific value</td>
<td>10.7 – 12.8 kWh/Nm³</td>
</tr>
<tr>
<td>Dew Point Hydrocarbons (at grid pressure)</td>
<td>&lt; -10°C</td>
</tr>
<tr>
<td>Dew Point Water (at grid pressure)</td>
<td>&lt; 10°C</td>
</tr>
<tr>
<td>Oxygen</td>
<td>&gt; 0.5% wet grid and &lt; 1.0% dry grid</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>&lt; 6.0 vol. %</td>
</tr>
<tr>
<td>Oxygen</td>
<td>&lt; 1.0 vol. %</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>&lt; 5 mg/ Nm³</td>
</tr>
<tr>
<td>Total sulphur</td>
<td>&lt; 30 mg/ Nm³</td>
</tr>
<tr>
<td>Ammonia</td>
<td>Free</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>&lt; 0.2 vol %</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>8 bar - 16 bar</td>
</tr>
<tr>
<td>Gas temperature</td>
<td>-10°C – 20°C</td>
</tr>
<tr>
<td>Capacity</td>
<td>ca. 3.0 Mio Nm³ or 350 Nm³ per hr</td>
</tr>
</tbody>
</table>

Table 17: Biomethane quality specified for the Homberg-Efze Facility

Luxembourg

In Luxembourg, the upgrading and injection of biomethane into the natural gas grid has increasingly gained in importance. The reasons for this are the lucrative state subsidies for the injection of biomethane and the insufficient outlets for heat utilisation from CHP at the respective locations and the associated loss of energy.
Legislation dealing with the regulation of injection conditions and payments is currently being developed, according to which the injected biomethane is valued at €6.0 - 6.5 per kWh (value as of March 2011). The adoption of this legislation is expected within the next few months. Plants currently in operation or construction that upgrade and inject biomethane to the grid are listed in Table 18.

<table>
<thead>
<tr>
<th>Location</th>
<th>Feedstock</th>
<th>Upgrading Process</th>
<th>Start of operation</th>
<th>Biomethane feed (m³/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mondercange</td>
<td>Bio waste, energy crops, (30,000 tpa)</td>
<td>Amine scrubbing</td>
<td>2011</td>
<td>1,600,000</td>
</tr>
<tr>
<td>Kehlen</td>
<td>Slurry, manure, energy crops, biowaste (50,000 tpa)</td>
<td>PWS</td>
<td>2010</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Itzig</td>
<td>Slurry, energy crops, manure, biowaste (45,000 tpa)</td>
<td>PWS</td>
<td>2011</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

Table 18: Biomethane injection plants in Luxembourg

The syndicate Minett-Kompost is an association of local authorities that collect and treat garden waste from 22 municipalities with a total of 180,000 inhabitants in the South of Luxembourg. The syndicate has operated a composting plant for the past 15 years. As a result of the steadily increasing quantities of green waste, a decision was made in 2005 to increase the processing capacity through the construction of an AD facility for the processing of 30,000 tpa of food and garden waste as well as energy crops.

Characteristics of the Minett-Kompost digestion plant in Mondercange are shown in Table 19.

| Capacity | 30,000 tpa |
| Feedstocks | Biowaste, green waste, energy crops |
| Technology digestion und composting | Dry digestion in a lying fermenter followed by composting of the digestate in tunnels (Strabag) |
| Biogas production | Ca. 2,800,000 m³ per year |
| Biomethane production | Ca. 1,600,000 m³ per year |
| Compost production | Ca. 7,000 tpa |
| Gas injection and purchases | Public Grid SUDGAZ SA |
| Construction time | 2 years |
| Start of operation | March 2011 |

Table 19: Details of Mondercange biomethane injection facility

As efficient use of the heat could not be identified at the plant location, it was decided to upgrade and inject the gas into the local grid of SUDGAZ SA. This project was classified as an official pilot project on the injection of biomethane by the Grand Duchy of Luxembourg and is part of the national carbon dioxide allocation plan.
Figure 18: Installation of the biogas upgrading plant at Mondercage

Amine gas treatment (by the contractor Strabag) was chosen to upgrade the biogas because of its small methane loss compared with other upgrading technologies (less than 0.25%) and its low investment and running costs as it does not require a pressure increase.

The basic components of the amine scrubbing plant are:

- Washing tower (counter current wash, cold water)
- Washing tower (counter current wash, amine dilution)
- Heat exchanger
- Compression to mains system pressure
- Biogas drying

The lower pressure (50-100 mbar) biogas with a methane content of 50-60% is cooled in a scrubbing tower with cold water for the purpose of condensate separation.

In a further washing tower, the carbon dioxide and hydrogen sulphide are absorbed through an amine dilution (Diethanolamine) and thus removed from the gas flow. The purified biogas with a methane content of > 97% is extracted at the top of the tower. The purified biomethane is further cooled in a heat exchanger and subsequently compressed to the required grid pressure of maximum 4 bar. Gas that does not comply with the required quality criteria is extracted ahead of this and deflected towards a flare.

Finally the biomethane is dried in dryers filled with silica gel to reach the required water content, odorised and adjusted to the required calorific value with the help of propane gas.

The removed quantities of carbon dioxide and hydrogen sulphide are subject to a separate purification process ahead of their release into the atmosphere.

Table 20 shows the estimated gas quality and quantity as well as further parameters after the gas upgrading. This corresponds to the specified requirements of the resident grid provider SUDGAZ SA.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane content</td>
<td>&lt; 97 vol.%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>&lt; 2.5 vol. %</td>
</tr>
<tr>
<td>Oxygen</td>
<td>&lt; 1 vol. %</td>
</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>&lt; 5 mg/ Nm³</td>
</tr>
<tr>
<td>Injection pressure</td>
<td>2.5 - 3 bar (max. 4 bar)</td>
</tr>
<tr>
<td>Water content</td>
<td>Dew point - 80 °C</td>
</tr>
<tr>
<td>Methane loss</td>
<td>&lt; 0.25 Vol. %</td>
</tr>
<tr>
<td>Propane gas admixture</td>
<td>Ca. 7 vol %</td>
</tr>
<tr>
<td>Quantity</td>
<td>Ca. 1.6 mio. Nm³ or ca. 180 Nm³ per h</td>
</tr>
</tbody>
</table>

**Table 20: Biomethane quality at Mondercange**

The levels of methane, hydrogen sulphide and dew point (water content) of the biomethane are monitored online. If the required critical values are not reached, the gas is initially fed into an internal cycle for further upgrading. If subsequently the critical values are still not met, the gas is either fed to a separate flare or back into the gas container.

**Sweden**

The gas grid is not widely developed in Sweden and therefore most biomethane is used as a transport fuel. However, there are at least 8 plants upgrading gas and injecting it to the gas grid. In 2006 1.2 TWh of biogas was produced with 55% used for heat production, 19% used as a vehicle fuel, 13% was flared, 8% used for electricity production and 4% for grid injection. Of the 34 upgrading plants 25 use the water scrubber technique, 7 use PSA, and 2 use amine scrubbing.