Implementation of anaerobic digestion in the UK, California and Germany

A report produced for the Farmers Club by

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Executive summary

Anaerobic digestion is a naturally occurring process in which biodegradable material is converted to biogas and a semi-solid material (digestate) by micro-organisms in the absence of oxygen. The anaerobic digestion process occurs naturally in landfill sites and slurry storage vessels, but the process can be engineered and optimised in dedicated anaerobic digestion plants to maximise the biogas yield and overall efficiency of the process. Generally biogas is burnt to produce heat and electricity, but it is also possible to upgrade the biogas to 98 % methane and to inject it into the national gas grid for more widespread consumption.

The implementation of commercial and farm anaerobic digestion plants in the UK is in its infancy, with approximately 60 plants currently in operation. In contrast there are over 6,000 anaerobic digestion plants operating in Germany. I obtained funding from the Farmers Club to travel to Germany to understand how the anaerobic digestion sector has developed. I learnt the main stimulus for market growth within the German sector was introduction of the Renewable Energies Act (EEG) in 2000. Whilst the Electricity Feed-In Act that was introduced in 1991 required electricity grid operators to purchase renewable electricity, the EEG increased the remuneration received by renewable electricity generators to a level that supported market growth. As a consequence the number of anaerobic digestion plants operating in Germany increased from approximately 1,000 plants in 2000 to over 6,000 plants in 2011.

Prof. Dr.-Ing Frank Scholwin (DBFZ Deutsches Biomassforschungszentrum gemeinnützige GmbH) explained the main feedstocks used in German anaerobic digestion plants are biogas crops (e.g. maize silage) and animal manures. This is because under the EEG, anaerobic digestion plants that use biogas crops and animal slurries as feedstock receive additional tariffs over the basic renewable electricity tariff (Table I).

Table I: Basic and bonus tariffs available under the EEG 2009. Tariffs are shown in units of cent/kWh

		< 150 kW	< 500 kW	< 5 MW
Basic tariff		11.67	9.18	8.25
Clean air bonus	Old plants	1.0	1.0	
	New plants	1.0	1.0	
Renewable primary products bonus (new plants)		7.0	7.0	4.0
Landscape work bonus (new plants)		2.0	2.0	
Bonus for use of manure (new plants)		4.0	1.0	
Bonus for innovative technologies (without gas injection into the grid)		2.0	2.0	2.0
Bonus for innocative technologies (Gas injection)	New plants	Depending on the size of the gas treatment 1 or 2 Cent/kWh		
	Old plants		2.0	
Combined Heat and Power bonus		0/2/3	0/2/3	0/2/3

(German Biogas Association, 2011)

In 2008 the Gas Network Access Ordinance (GasNZV) was revised in Germany. The ordinance places an obligation on gas grid operators to grant preferred access to anaerobic digestion plants that have requested access to the gas grid. The regulation requires the grid operator to pay 75 % of the costs of grid access for distances of less than 1 km. The anaerobic digestion plant operator must fund the remainder up to a maximum of €250,000. It is anticipated the revised GasNZV will increase the number of anaerobic digestion plants upgrading biogas for injection into the gas grid from 2 plants in 2006 to 121 plants by 2013. The advantages of upgrading biogas to biomethane for injection into the gas grid include:

- More efficient use of biogas. Typically the combustion of biogas on-site at anaerobic digestion plants results in 30 % - 35 % of the energy in the gas being harnessed. If biomethane is injected into the gas grid it can be used in modern domestic boilers that are associated with efficiencies in excess of 90 %.
- Greater competition for renewable gas as the biogas producer is able to access a larger market that if the biogas is sold and used locally.

During my visit to Germany I visited a number of anaerobic digestion plants, including a biogas upgrading and grid injection plant that is located adjacent to a farm anaerobic digestion plant in Maihingen (Fig. I). The anaerobic digestion plant is owned by a group of farmers. The plant uses 40,000 tonnes of feedstock each year, of which 75 % is maize silage, 20 % grass silage, and 5 % cereal crops (whole plants). The anaerobic digestion plant produces approximately 500 m^3 of biogas each hour, which is supplied to the biogas upgrading plant. The digestate produced by the plant is separated into a solid and liquid fraction. The liquid digestate is used as a fertiliser on local crop land, whilst the solid digestate is used to form a 20 cm cover on the silage (Fig. II). The operators of the plant stated the use of solid digestate for this process is beneficial compared to a foil cover because losses are reduced by between 8 % and 10 %.

Fig. I: Biogas upgrading plant, Maihingen

Fig. II: Use of solid digestate as a cover on maize silage

The biogas upgrading plant uses a pressurised water scrubber to remove most of the carbon dioxide and hydrogen sulphide contained in the biogas to produce biomethane with a methane content of approximately 98 % and pressure of 6 bar. Propane is added to the biomethane to increase its energy content so that it is equivalent to natural gas. To connect to the gas grid a 4 km pipeline was installed from the upgrading plant to the grid connection point. The gas grid to which the plant connects to is a low pressure grid that operates at 6 bar, hence there is no need to compress the biomethane prior to injection. This reduces the capital and operating costs of the plant in comparison to a plant connecting to a higher pressure gas grid.

As in the UK, anaerobic digestion is an underdeveloped sector in California. Valentino Tiangco (Sacramento Municipal Utility District) explained that current installed electrical capacity of biogas in California is 344.74 MW. The majority of this electrical capacity (64 MW) originates from the anaerobic digestion of wastewater (e.g. sewage). The contribution of farm anaerobic digestion is comparatively small at 5.7 MW. Similarly to the UK there is enormous potential for growth in the anaerobic digestion sector within California. I travelled to California to understand how the anaerobic digestion sector is developing to enable comparison with UK development.

Chris Voell (AgSTAR) explained that there are currently 15 farm anaerobic digesters in operation in California, but that there is potential for many more to be installed as illustrated in Fig. III.

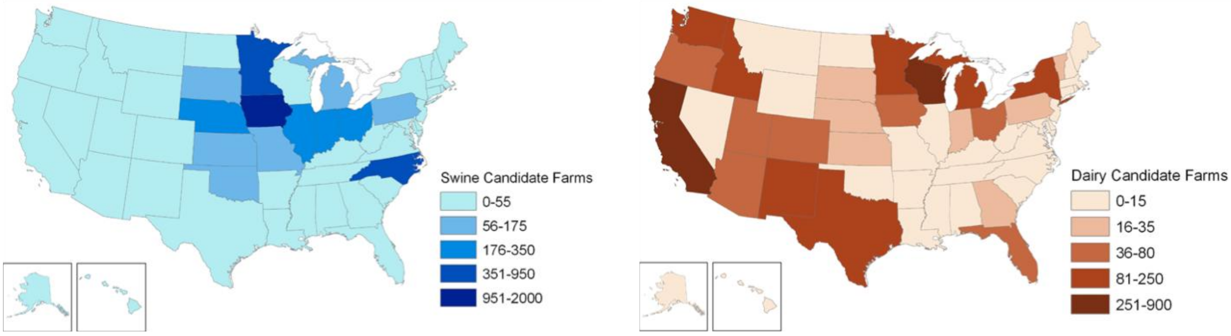

Fig. III: Geographical spread of U.S. anaerobic digestion candidate farms (Source: AgSTAR undated)

In addition to farm anaerobic digestion plants, it is anticipated the number of anaerobic digestion plants that treat Municipal Solid Waste (MSW) will increase in California. Ken Decio (Department of Resources, Recycling and Recovery) explained his department had been set a target to reduce the amount of biodegradable waste sent to landfill by 50 % by 2020. It is anticipated to meet this target approximately 3.5 million tons of MSW would be diverted to approximately 70 anaerobic digestion plants (currently there are no dedicated MSW anaerobic digestion plants in California).

Whilst there is significant potential for the development of farm anaerobic digestion plants in California, fulfilment of this potential is currently stunted for several reasons. Whilst California Assembly Bill 1969 (passed in 2006) authorises the introduction of renewable electricity feed-in tariffs for the purchase of renewable electricity by electricity companies, these tariffs have yet to be introduced. The permitting requirements in California for anaerobic digestion are complicated for several reasons:

- Whilst some regulatory agencies have specific rules relating to anaerobic digestion, other agencies (e.g. water agencies) do not. This means each application that these agencies receive in relation to anaerobic digestion must be treated on a case by case basis making the permitting process arduous and complex.
- The Clean Water Act 1972 limits the range of feedstocks that can be used in on-farm anaerobic digestion plants to those produced on farm (e.g. animal slurries and energy crops). Surface and groundwater in California has increased levels of salinity due to the state's arid climate, importation of water, and large agricultural industry. The State Water Resource Board is concerned that the use of off-farm feedstocks (e.g. food waste) in farm anaerobic digesters will result in the production of a digestate whose composition is unpredictable in terms of salt concentration (including Na^+, K^+, and Cl^-).
- California has stringent air emission standards that are particularly strict in the areas of California where most livestock farmers are located. The combustion of biogas produces emissions above those permissible under the standards in these livestock areas. Ultimately the air emissions standards prevent the implementation of anaerobic digestion in these areas because the technology that would need to be employed to meet the standards would make the development unviable.

During my visit to California I visited Fiscalini Farm (Modesto) where an anaerobic digester had been installed to convert manure from 1,500 dairy cows to electricity and heat. The anaerobic digestion plant took 3 years to build from conception to operation. This included 2 years of fighting with regulators, which demonstrates the regulatory challenge associated with anaerobic digestion in California. Similarly to the plant in Germany, the liquid digestate is used as a fertiliser. However, the solid digestate is dried and used as animal bedding. Nettie Drake (Ag Power Development) explained that the somatic cell count of the dairy cows had reduced from 200,000 to less than 100,000 since the digestate had been used as bedding material. The biogas produced by the plant is burnt to produce electricity that is fed into the electricity grid and heat that is used on the farm. Prior to implementation of the plant, Fiscalini Farm used propane to heat the dairy barns, pasteurise milk, and to heat the cheese factory located on-site. Following implementation of the plant Nettie Drake suggested the farm saves $77,220 per annum by no longer needing to purchase propane.

In conclusion development of the German anaerobic digestion sector has been supported by the Renewable Energies Act that provides financial incentives for the application of anaerobic digestion, in addition to a simple permitting and regulatory process. In contrast the anaerobic digestion sector is underdeveloped in California due to a lack of financial support and due to complicated, strict and arduous permitting requirements/ processes. Whilst the anaerobic digestion sector is also underdeveloped in the UK, recent developments that include the introduction of the renewable electricity Feed-In Tariff and simplified permitting procedures should support development of the sector to help it fulfil its potential.

References

AgSTAR (undated) Operating Anaerobic Digester Projects. [On-line] http://www.epa.gov/agstar/projects/index.html Accessed 14th June 2011

German Biogas (2011) The Development of the German biogas sector. Proceedings of the 20th Annual German Biogas Association Conference and Trade Fair. 11th – 13th January 2011

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I would like to thank the Farmers Club for the travel bursary that provided me with the opportunity to travel to Germany and California to learn about the anaerobic digestion market sectors within these countries.

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1.0 Personal reasons for undertaking the study

Funding was obtained from the Farmers Club to visit Germany and California with the aim of comparing and contrasting approaches to the development of the Anaerobic Digestion (AD) sector. The main reasons why I undertook the project were to:

1. Further my understanding and knowledge of the application of Anaerobic Digestion (AD) and to enable me to increase the quality of my teaching through dissemination of this understanding and knowledge.

2. Increase my understanding of the knowledge gaps that exist within the AD sector, to ensure the research I conduct can fulfil these knowledge gaps and contribute to development of the sector.

3. Fully understand the opportunities and difficulties that exist within the AD sector, to enable this knowledge to be disseminated to potential AD adopters through dissemination events.

4. Enhance my reputation within the bioenergy sector with the view to facilitating future research and knowledge transfer opportunities.

2.0 Introduction to Anaerobic Digestion

Anaerobic Digestion (AD) is a naturally occurring process in which biodegradable material is converted into biogas and a semi-solid material by micro-organisms in the absence of oxygen. The AD process occurs naturally in landfill sites and slurry storage vessels, but the process can be engineered and optimised in dedicated AD plants to maximise the biogas yield and the overall efficiency of the process.

The biogas generated during AD is composed of approximately 60% methane, 40% carbon dioxide and trace compounds such as hydrogen sulphide; although the exact composition varies dependent on the material degraded. The biogas produced is a versatile fuel that can be burnt to produce heat and/or electricity, upgraded (removing carbon dioxide and trace elements) and used as a road transport fuel, or potentially injected into the national gas grid. The semi-solid material produced by the AD process is referred to as digestate and provides an alternative fertiliser and soil conditioner to mineral fertilisers and virgin materials.

In addition to providing a renewable source of energy, anaerobic digestion provides a number of further benefits. The benefits depend somewhat on the type of organisation involved in an anaerobic digestion development.

With regards to farmers, anaerobic digestion can:

- Provide a diversification opportunity.
- Convert animal slurries into a fertiliser in which nitrogen is more readily available to crops.
- Kill pathogens and seeds present in the feedstock preventing the spread of disease and weeds.

With regards to the food industry, anaerobic digestion can:

- Reduce the cost of sending food waste to landfill or for incineration.
- Improve rodent and vermin control.
- Improve company image through green PR.

With regards to the local community, anaerobic digestion can:

- Reduce the odour associated with animal slurries by up to 80%, reducing odour nuisance.
- Potentially provide renewable heating through a district heating scheme.
- Create employment opportunities.

The environmental benefits of anaerobic digestion are numerous and include:

- The reduction of greenhouse gas emissions through the displacement of fossil energy, capture of methane produced naturally during slurry storage and reduction in the consumption of mineral fertiliser.
- Reducing nitrate pollution by reducing run-off to waterways as nitrate is more readily available to crops.
- Reducing the amount of biodegradable waste sent to landfill.

3.0 Context of the award:

Anaerobic Digestion (AD) can be used on farms to process animal slurries, purpose grown energy crops (e.g. maize), other agricultural residues, and food waste. The UK produces approximately 100 million tonnes of organic material each year that could be used as feedstock for AD, including 90 million tonnes of agricultural material and between 12 and 20 million tonnes of food waste.

AD has the potential to play an important role in the delivery of UK, EU and global targets, which include:

- Reducing carbon dioxide emissions by 34 % by 2020 and 80% (below 1990 levels) by 2050, as detailed in the UK Climate Change Act 2008.
- Producing 15% of energy (approximately 240 TWh) from renewable sources by 2020, as specified in the EU Renewable Energy Directive.
- Reducing the amount of biodegradable waste sent to landfill to 35 % of 1995 levels by 2020, as detailed in the EU Landfill Directive.
- Reducing emissions of six greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydroflurocarbons and perflurocarbons) by 12.5 % compared to 1990 levels between 2008 and 2012, as specified in the Kyoto Protocol.

Within the UK the National Farmers Union (NFU) has a vision for 1,000 on-farm digesters by 2020, whilst the UK Renewable Energy Strategy 2009 indicated the technical potential of AD for heat and power is at least 10 TWh to 20 TWh, and possibly as much as 27 TWh. In 2007 approximately 5.3 TWh of electricity was produced from biogas, predominantly from landfill gas with a small proportion generated from the anaerobic digestion of sewage sludge (in 2010 approximately 0.8 TWh of electricity is expected to be produced from sewage sludge). Accordingly, and with specific reference to UK farming, AD presents a significant opportunity for rural diversification, employment creation, and enhancing economic activity within the countryside.

The report by the UK Anaerobic Digestion Task Group 'Developing an implementation plan for Anaerobic Digestion' published in July 2009 identified key challenges that must be addressed to enable AD to fulfil its potential within the UK. In light of these challenges funding was obtained from the Farmers Club to:

- Gain knowledge and understanding from Germany where Anaerobic Digestion is more established.

- Compare the approaches of the USA and UK to the development of the AD sector [AD is underdeveloped in both countries].

Specific objectives were:

1. Comparison of the most commonly used feedstocks, and the format of the supply chains associated with these feedstocks.
2. Comparison of the scale and type of AD technology used in each country.
3. Understanding the financial and policy support mechanisms provided for AD in each country and the impact of this support on the sector. For example, feed-in regulations in

Germany have resulted in suppliers concentrating on optimising 500kW (electricity) digesters.

4. Identifying the uses of digestate.
5. Understanding the requirements for biomethane injection into the national gas grid.

4.0 Why Germany?

Germany is considered to be a world leader in the application of on-farm and commercial AD systems. Over the past five years the number of AD plants in Germany has doubled to approximately 6,000, with an associated fourfold increase in electrical generation. Most (98 %) of the of biogas plants in Germany use energy crops as feedstock due to relatively high feed-in tariffs for small biogas plants, in addition to the provision of high premiums for purely renewable agricultural substrates.

4.1 Appointments/visits in Germany

I visited Germany to attend the 20th Annual Biogas Conference and Biogas Trade Fair that was held in Nuremberg between the 11th and 13th January 2011. Presentations of particular interest during the conference are shown in Table 1.

Table 1: 20th Annual Biogas Conference presentations of particular interest to the current study

Presenter	Organisation	Presentation Title
Stefan Thurner	Bayerische Landesanstalt für Landwirtschaft	Process engineering for the production of gas ensilage – overview, comparison and options for optimisation
Dr. Ing. Eric Werner-Korall	DQS SmbH	Initial experience with the certification of biogas plants on the basis of the European Sustainability Regulation
Talf Block	Ingenieurbüro BIGATEC	Latest development in water legislation.
Dr. Helmut Liobl	Paluka, Sobola, Loibl & Partner	EEG 2012 – an outlook
Prof. Dr.-Ing. Frank Scholwin	DBFZ Deutsches Biomassforschungszentrum gemeinnützige GmbH	Report on experience with EEG 2009 – conclusions for further development
Dr. Birgit Vollrath	Bayerische Landesanstalt für Weinbau und Gartenbau	Energy from wild-type plants
Prof. Dr. Kurt Jürgen Hülsbergen	Wissenschaftszentrum Weihenstephan für Ernährung, Landntzung und Umwelt	Impact of biogas systems on the hummus supply of arable soil – options for optimisation
Dr. Martin Altrock	Becker Büttner Held	Gas network access ordinance, legal and political framework of biogas transport
Georg Raglinger	Erdas Schwaben GmbH	2 methods and 3 suppliers: How does gas treatment really work?

The Biogas Trade Fair included over 340 exhibitors. Organisations of particular interest at the Trade Fair included the anaerobic digestion technology providers: BD Agro Renewables GmbH, Biogas Nord GmbH, MT Energie GmbH, and AAT Biogas technology GmbH.

I attended a one day study tour on Friday 14th January 2011, during which I visited the following anaerobic digestion sites:

- A farm anaerobic digestion plant with gas feed-in system in Maihingen.
- A farm anaerobic digestion plant in Triesdorf.
- A commercial anaerobic digestion plant at Seebronn.

4.2 Biogas plant with gas feed-in system, Maihingen

The biogas plant is a continuously mixed anaerobic digestion plant that uses 40,000 tonnes of energy crops as feedstock each year. The composition of this feedstock is approximately 75 % maize silage, 20 % grass silage and 5 % cereals (whole plant). Approximately half this feedstock is provided by the farmers involved in the plant, whilst the remainder is purchased on the free market. The anaerobic digestion plant was built in 1999 and expanded in 2004 by the addition of a second anaerobic digestion tank. The anaerobic digestion plant is operated and owned by a number of local farmers.

The digestate produced by the anaerobic digestion system is separated into a liquid and a solid fraction. The liquid is used as fertiliser, whilst the solid is used to form a 20 cm cover on the silage. The operators of the plant stated the use of solid digestate for this purpose is beneficial compared to using a foil cover because losses are reduced by 8 – 10 %. Essentially this reduces the loss of energy from the silage during storage. Fig. 1 is a photograph showing the solid digestate cover on top of maize silage at the site. The digestate can be seen as a dark brown colour on the top of light brown silage.

Fig. 1: Use of solid digestate as a cover on maize silage, Maihingen (Source: Authors own)

The anaerobic digestion system produces approximately 500 m^3 of biogas each hour, which is stored in a gas bag before use. The biogas produced by the anaerobic digestion plant is upgraded and injected into the national gas grid in an upgrading plant that is located adjacent to the anaerobic digestion plant (Fig. 2). The upgrading plant is owned by the company Erdgas Schwaben GmbH. The biogas is upgraded using pressurised-water scrubbing in a 2 MWe biogas treatment plant. This removes most of the carbon dioxide and trace elements from the biogas, upgrading it to biomethane with a methane content of 98 %. The biomethane leaves the water scrubber at a pressure of 6 bar and energy content of 10.7 kWh/ m^3. Propane is added to the biomethane to increase the calorific value of the gas so that it is equivalent to the natural gas supplied through the gas grid. To connect to the gas grid a 4 km pipeline was installed from the upgrading plant to the grid connection point. The gas grid operates at a pressure of 6 bar, so the pressure of the biomethane produced by the upgrading plant does not need to be increased.

Fig. 2: Biogas upgrading plant, Maihingen (Source: Authors own)

4.3 Biogas plant, Triesdorf

The biogas plant in Triesdorf is a 150 kWe anaerobic digestion plant that is located at an agricultural college and was commissioned in June 2009. The anaerobic digestion plant provides base load heating for the site through a district heating scheme. The plant uses 10 m^3 of liquid manure, 2 tonnes of solid manure, 4 tonnes of grass, and 4 tonnes of maize silage as feedstock each day. The anaerobic digestion system uses a primary and secondary mesophilic (operated at 43 °C) fermenter, as at Maihingen. The retention time of feedstock in the digester is 150 days. The biogas generated is burnt in a 195 kWe Combined Heat and Power (CHP) unit to produce heat and electricity for the site. The digestate produced is applied to land as fertiliser. Fig. 3 shows the two anaerobic digestion tanks and CHP unit at the site.

Fig. 3: Biogas plant at Triesdorf showing the two anaerobic digestion tanks and Combined Heat and Power unit (Source: Authors own)

4.3 Biogas plant Seebronn

The third anaerobic digestion plant visited uses approximately 18,200 tonnes of food waste as feedstock each year. Normally this feedstock is obtained at no cost to the plant, but a gate fee is not usually gained. The feedstock includes abattoir waste, supermarket waste, and catering waste. Due to the presence of animal by-products the waste is pasteurised at 70 °C for 1 hour. The anaerobic digestion system employs a primary and secondary digester. Most biogas is produced in the primary digester (70 % - 80 %), but the methane content of biogas produced in the secondary fermenter is higher. The plant produces approximately 16,000 tonnes of digestate each year that is used on farmland as fertiliser.

5.0 Why California?

It is estimated the USA generates 200 million tons of municipal waste each year, of which 80 % is biodegradable. Additionally it is estimated 335 million tons of livestock and poultry manure is produced annually. Forecasts suggest this biomass has the potential to meet 50 % of the natural gas demand in the USA through AD. Over the past 5 years financial support has aided development of AD on livestock farms, with the amount of electricity generated increasing from less than 0.02 TWh in 2001 to 0.24 TWh in 2008. In 2008 there were approximately 125 digesters operating on-farm in the USA. To date biogas production from food waste in the USA is underdeveloped, whilst investment in biogas recovery from sewage treatment is decreasing due to technological problems. The USA and UK can be considered to be in a similar situation, whereby AD is currently under-utilised, but whose potential is recognised and actions are being taken to increase implementation. Whilst the trend in the UK is for continuously mixed digesters, in the USA approximately 65 % of digesters are plug-flow, 35 % are continuously mixed and 22 % are covered lagoons.

The area of study within the USA was the state of California. In 2006 10.61 % of California's electricity was produced from renewable sources, with 2.08 % of electricity produced from biomass. This bioenergy was generated from biomass combustion (600 MW) and biogas captured from landfill sites or anaerobic digestion of sewage sludge, food waste and animal slurries (360 MW). In total 7.3 GWh of electricity was produced from biomass in 2005. In November 2008 the Governor of California raised renewable energy goals for the state to 33 % renewable energy by 2020. The Governor directed several state agencies, including the California Energy Commission, to make major steps towards the use of biomass to produce renewable electricity. With regards to AD, research by the California Energy Commission estimates that less than 1 % of livestock manure produced in California is utilised, and that if this manure were used as a feedstock for AD the installed AD generation capacity would be approximately 105 MW.

5.1 Appointments/visits in California

I attended the Biogas USA Conference and Trade Fair held in San Francisco between the 13th and 14th October 2010. Presentations of particular interest during the conference are shown in Table 2.

Table 2: Biogas USA Conference presentations of particular interest to the current study

Presenter	Organisation	Presentation Title
Valentino Tiangco	Sacramento Municipal Utility District	Biogas: Challenges and Opportunities in the Energy Supply Chain
Daniel LeFevers	Gas Technology Institute	Renewable biogas an opportunity for the nation
Jaques Franco	Department Resources, Recycling and Recovery (CalRecycle)	Biogas from urban derived biomass in California: an update
Chris Voell	AgSTAR	Advancing energy independence with environmental benefit: livestock manure digesters
Philip Brown	US Department of Agriculture Rural Development	Energy programs – 2008 Farm Bill
Allen Dusault	Sustainable Conservation	Farm biogas and biogas in CA – 2010 opportunities and barriers
Nettie Drake	Ag Power Development	Agricultural biogas production – Fiscalini Farms project experience

On the 15th October 2010 I attended the post-conference workshop that included an overview of the challenges facing US dairy farmers in relation to anaerobic digestion. The workshop included a site visit to Fiscalini Farm that installed an anaerobic digestion system in 2009.

I returned to California in April 2011 to meet with:

- Ken Decio (Senior Integrated Waste Management Specialist at the Department of Resources, Recycling and Recovery: CalRecycle)
- Angela McEliece RCM International LLC (an anaerobic digestion technology provider)
- The Castelanelli Brother Dairy to see an anaerobic lagoon digester.
- Cheri Chastain (Sustainability Officer at the Sierra Nevada Brewing Company)
- Jared Gill and Laura Hamman (Assistant Facilities Manager and Sustainability Coordinator at Gills Onions, respectively)

I met with Cheri Chastain, Jared Gill and Laura Hamman to learn about the use of fuel cells with anaerobic digestion. The findings of these meetings will be discussed in a separate report.

5.2 Fiscalini Farm Anaerobic Digester, Modesto

Fiscalini Farm is a dairy farm with 1,500 cows. The farm installed an anaerobic digestion plant in 2009. Prior to construction of the anaerobic digestion plant all manure was separated into a solid and liquid fraction. The solid fraction was dried and used as animal bedding. The farm decided to implement an anaerobic digestion plant to generate alternative revenue streams. Currently the anaerobic digester is the only part of the farm that is making money, as milk prices are currently low. Fig. 4 provides an aerial view of Fiscalini Farm and the location of the anaerobic digestion plant (middle right of the figure). The anaerobic digestion plant is built on a small footprint because of limited land availability (as much land is needed as possible to spread the digestate produced by the anaerobic digestion plant).

Fig. 4: Aerial view of Fiscalini Farm (Source: Nettie Drake)

The feedstocks used in the anaerobic digester are a mixture of dairy slurry and sudan grass. The dairy slurry is pumped into settling ponds before it is fed into the anaerobic digester (Fig. 5). This is because the dairy slurry contains sand that must be removed so that sedimentation does not occur in the anaerobic digester. The sudan grass is augured into the anaerobic digester from a silo (Fig. 6). The anaerobic digestion plant includes two anaerobic digestion tanks that are operated in parallel at a temperature of approximately 40 °C (Fig. 7). The digestate produced is separated into a solid and liquid fraction (Fig. 8). The solid digestate is dried and used as animal bedding, whilst the liquid digestate is stored in a lagoon (Fig. 9) before it is applied to land as a liquid fertiliser. Nettie Drake explained that the somatic cell count of the dairy cows has dropped from 200,000 to less than 100,000 since digestate has been used as bedding material.

Fig. 5: Dairy slurry settling pond at Fiscalini Farm (Source: Authors own)

Fig. 6: Sudan grass storage silo at Fiscalini Farm (Source: Authors own)

Fig. 7: The two mesophilic anaerobic digestion tanks at Fiscalini Farm (Source: Nettie Drake)

Fig. 8: Separation of digestate into a solid and liquid fraction at Fiscalini Farm (Source: Authors own)

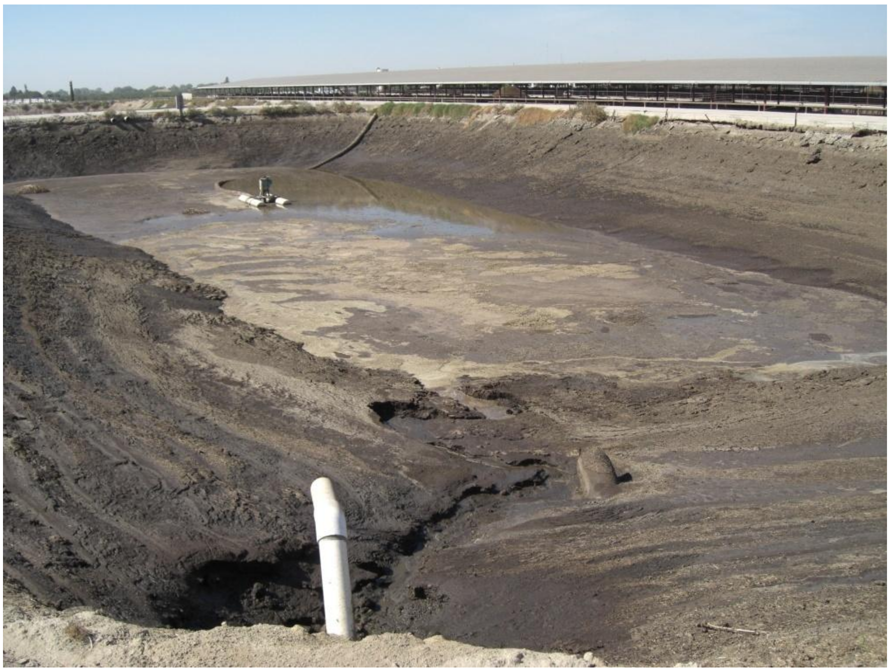

Fig. 9: Liquid digestate storage in a lagoon prior to land application at Fiscalini Farm (Source: Authors own)

The anaerobic digestion plant took 3 years to build from conception to operation. This included 2 years of fighting with the regulators, which demonstrates the regulatory challenge associated with anaerobic digestion implementation in California. The capital cost of the anaerobic digestion plant was $4.3 million.

The biogas produced by the anaerobic digestion plant is burnt in a 710 kWe Combined Heat and Power (CHP) unit. The electricity produced is exported to the grid and is enough to power 450 homes. The CHP currently operates at an efficiency of 53 %. If this efficiency could be increased to 80 %, then the plant would generate enough electricity to power 800 homes. Nettie Drake explained the relatively low efficiency of the CHP may be because:

- Not enough methane is being supplied. Originally the anaerobic digestion plant was designed to use off-site waste products but this has not been possible for regulatory reasons.
- Reduced digester efficiency due to the build up of sand in the digester tanks and inefficient mixing due to poor agitator design.

Prior to implementation of the anaerobic digestion plant Fiscalini Farms used propane to heat the dairy barns, pasteurise milk and to heat the cheese plant located on-site. Following implementation of the anaerobic digestion plant it is estimated the farm saves $77,220 per annum by no longer needing to purchase propane.

Excess heat is produced from the combustion of biogas in the CHP unit. Fiscalini Farms are currently considering options to use this heat. One option that is being considered is the growth of algae in the liquid digestate produced by the anaerobic digester. In addition to using excess heat, exhaust gases could also be directed through the lagoon and would help to reduce nitrous oxide emissions from the plant. The algae cultivated could then be used as feedstock in the anaerobic digestion plant or used as a fertiliser.

5.3 Castelanelli Brothers Dairy, Lodi

The Castelanelli Brothers Dairy is a family owned dairy with 1,600 milking cows and 1,200 heifers. The milking herd is housed in freestalls with sand bedding, whilst the heifers are housed in corrals. Prior to implementation of an anaerobic digestion plant at the farm the manure from these cows was stored in an earthen lagoon. To reduce greenhouse gas emissions during the storage of the manure a covered lagoon was installed at the dairy by RCM International LLC (an anaerobic digestion technology provider). The lagoon digester uses all of the manure produced by the milking cows and half the manure from the heifers as feedstock. The manure is flushed with liquid digestate through sand traps to a solids separator that removes large solids. The separated liquids are pumped to the anaerobic lagoon (Fig. 10). The anaerobic lagoon is unheated and is 200 ft wide, 500 ft long, and 20 ft deep. The retention time of manure in the digester is 40 to 60 days. The liquid digestate produced by the anaerobic lagoon is stored in an open lagoon prior to use as a fertiliser on the farms field crops (Fig. 11).

The anaerobic lagoon produces between 100,000 ft^3 and 165,000 ft^3 of biogas per day, depending on the season. The biogas is filtered using a biological scrubber and burnt in a natural gas engine (rated at an electrical capacity of 300 kW) that has been modified to run on biogas (Fig. 12). A portion of the electricity generated is used on-site, with the remainder sold and exported to the electricity grid. The average price the farm receives for exported electricity is $0.09/kWh.

Fig. 10: Anaerobic lagoon digester at Castelanelli Brothers Dairy (Source: Authors own)

Fig. 11: Storage of liquid digestate in an open lagoon at Castelanelli Brothers Dairy (Source: Authors own)

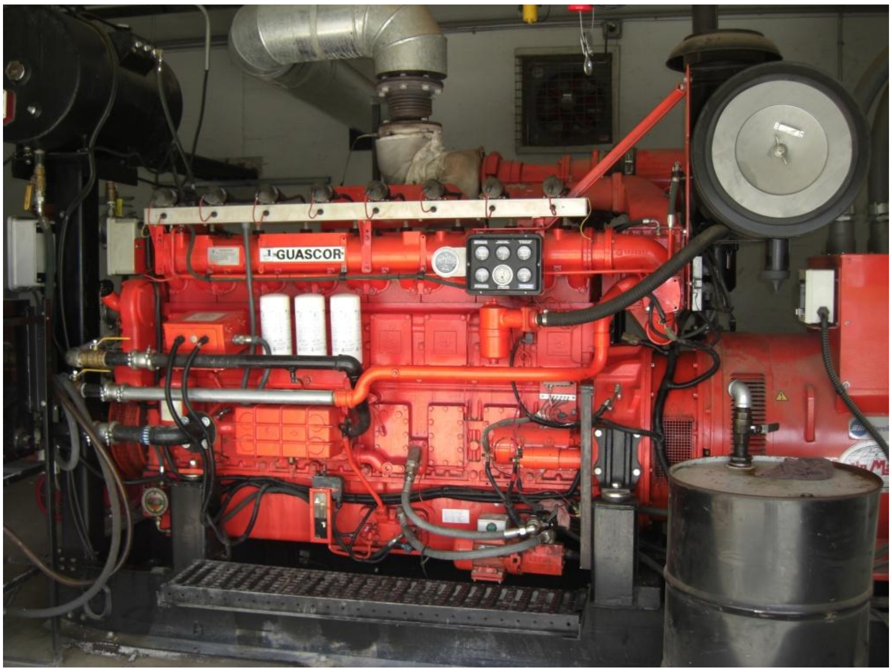

Fig. 12: Modified natural gas engine for production of electricity from biogas at Castelanelli Brothers Dairy (Source: Authors own)

6.0 Application of Anaerobic Digestion

6.1 Application of Anaerobic Digestion in the UK

Anaerobic digestion has been used for over a century by the sewage industry, where it is used as a stage in the sewage treatment process. There currently over 140 sewage anaerobic digestion plants in the UK, which generate approximately 0.8 TWh of renewable electricity each year. Table 3 details the number and size of UK sewage treatment plants according to Water Company.

Table 3: Number and capacity of UK sewage treatment anaerobic digestion plants

Water company	< 5,000 tonne p.a.	5,000 – 10,000 tonne p.a.	10,000 – 20,000 tonne p.a.	> 20,000 tonne p.a.
Anglian Water Services Ltd	3	2	0	3
Dwr Cymru Welsh Water	11	1	1	0
Northumbrian Water Ltd	6	1	0	1
Severn Trent Water Ltd	16	7	2	5
Southern Water	8	2	2	0
South West Water Ltd	8	1	0	0
Thames Water Utilities Ltd	9	4	1	1
United Utilities Water Ltd	10	7	3	2
Wessex Water Services Ltd	3	1	1	0
Yorkshire Water Services Ltd	15	1	4	0
Other	2	1	0	1
Total	**91**	**28**	**14**	**13**

(Anaerobic Digestion Portal, undated)

In addition to the sewage treatment anaerobic digesters listed in Table 3 the Anaerobic Digestion Portal (undated) suggests there are approximately 60 anaerobic digestion plants operating in the UK. Approximately half of these plants are located on farms. Fig. 13 shows the main feedstock used in off-farm anaerobic digestion plants in the UK is food waste that may be co-digested with animal slurry. A number of off-farm anaerobic digesters use ‘other’ feedstocks such as brewery waste and bakery waste.

Fig. 14 shows the main feedstock used in on-farm anaerobic digestion plants in the UK is animal slurry and manure that may be co-digested with other feedstocks such as food waste. There are 3 on-farm plants in the UK that co-digest food waste and energy crops.

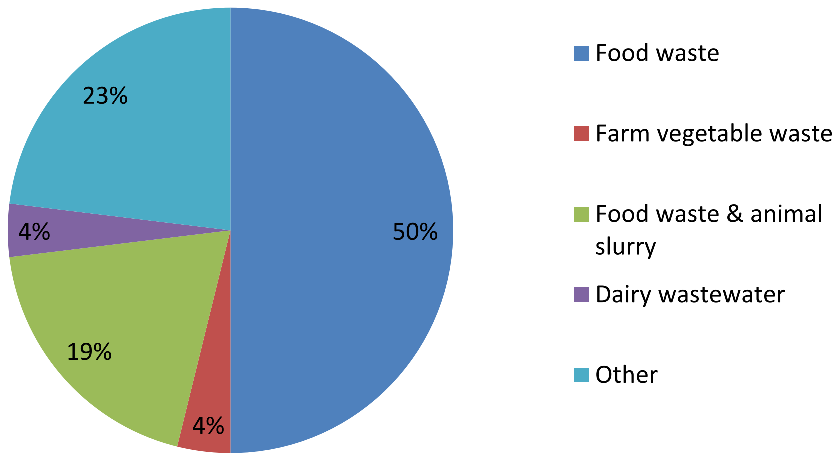

Fig. 13: UK off-farm anaerobic digestion feedstocks (adapted from the Anaerobic Digestion Portal, undated)

Fig. 14 shows the main feedstock used in on-farm anaerobic digestion plants in the UK is animal slurry and manure that may be co-digested with other feedstocks such as food waste. There are 3 on-farm plants in the UK that co-digest food waste and energy crops.

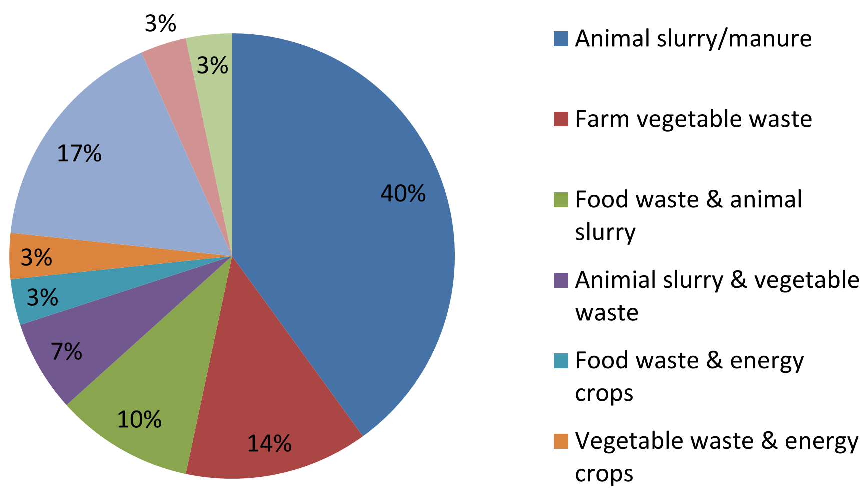

Fig. 14: UK on-farm anaerobic digestion feedstocks (adapted from the Anaerobic Digestion Portal, undated)

Generally off-farm anaerobic digestion plants are larger than farm plants in the UK, as can be seen from Fig. 15 and 16.

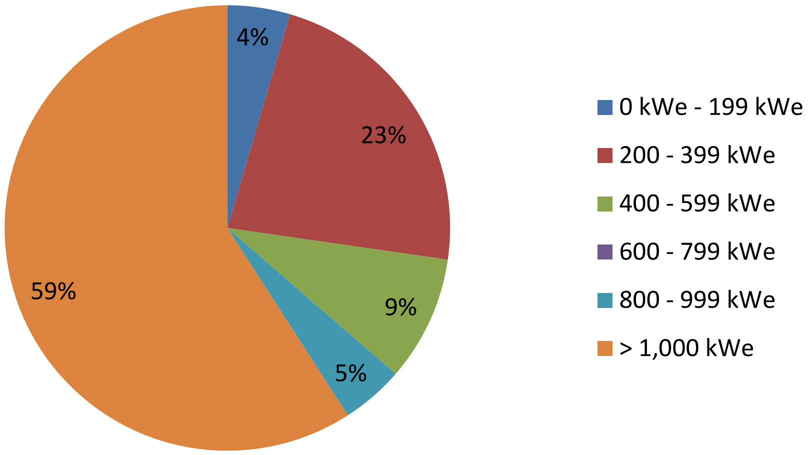

Fig. 15: UK off-farm anaerobic digestion plant electrical capacity (adapted from the Anaerobic Digestion Portal, undated)

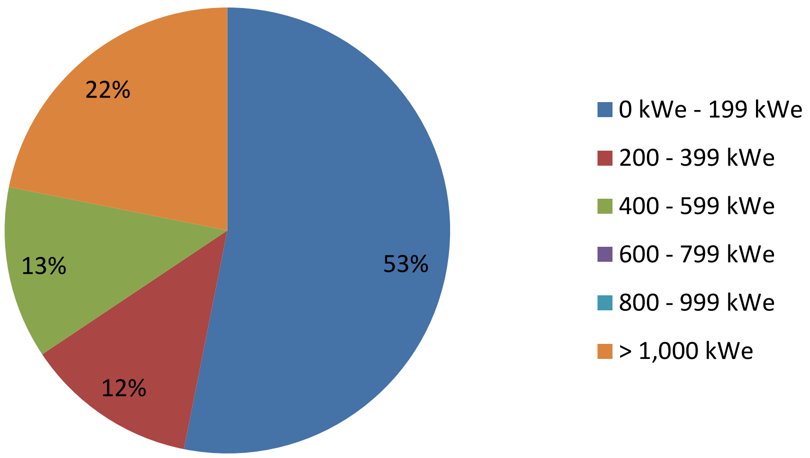

Fig. 16: UK on-farm anaerobic digestion plant electrical capacity (adapted from the Anaerobic Digestion Portal, undated)

6.2 Application of Anaerobic Digestion in the US and California

Valentino Tiangco (Sacramento Municipal Utility District) explained the current installed electrical capacity of biogas in California is 344.7 MW. The majority of this electrical capacity (275 MW) is from the collection and combustion of landfill gas. The second largest electrical capacity (64 MW) originates from the anaerobic digestion of wastewater (i.e. sewage). The contribution of farm anaerobic digestion is relatively small (5.7 MW).

There are currently 160 farm digesters operating in the United States, 80 % of which are installed on dairy farms and 15 % on swine farms. The total generating capacity from these digesters is 57.1 MW. The digesters are concentrated in California, Missouri, New York, Pennsylvania, Vermont and Wisconsin (Fig. 17). Chris Voell (AgSTAR) explained that within California there are 15 manure digesters operational, which collectively produce 28,670 MWh of electricity each year. These digesters are primarily covered lagoon digesters (10 out of the 16).

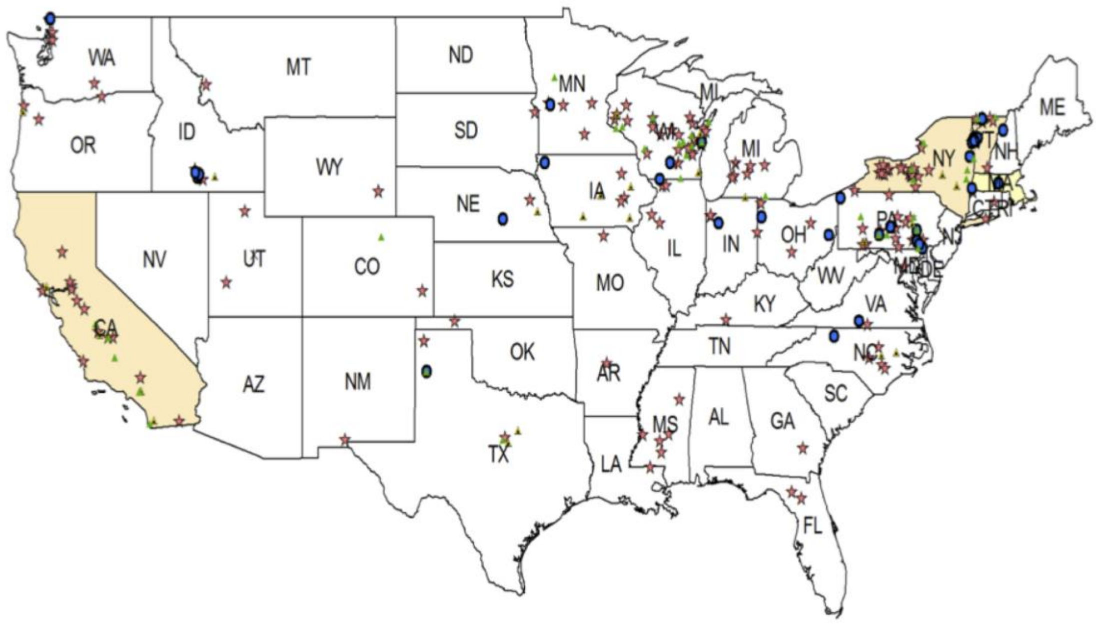

Fig. 17: Location of farm digesters in the United States (AgSTAR, undated)

Similarly to the UK most farm digesters in California are relatively small (Fig. 18).

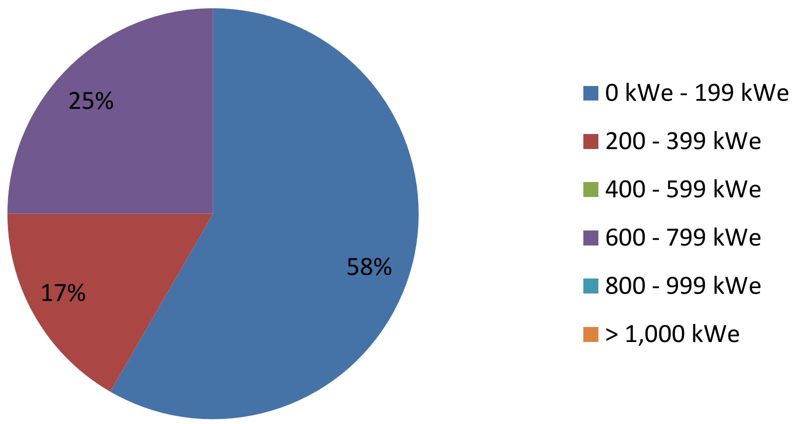

Fig. 18: Californian farm anaerobic digestion plant electrical capacity (adapted from AgSTAR, undated)

The Environmental Protection Agency, U.S. Department of Agriculture and U.S. Department of Energy have collaborated to deliver the AgSTAR programme, which is an outreach program designed to promote the use of biogas recovery from livestock waste. Chris Voell (National Programme Manager, AgSTAR) explained farm application of anaerobic digestion in California is far below its potential, suggesting there is opportunity for significant growth. The AgSTAR programme has identified 8,241 candidate farms in the U.S (Table 4). These farms are:

- Dairy farms with over 500 cows or swine farms with over 2,000 animals, with either anaerobic lagoons or liquid slurry management systems.
- Swine farms with over 5,000 animals with deep pit manure management systems.

Dairy farms present the largest opportunity for farm anaerobic digestion in California (Fig. 19).

Table 4: U.S. anaerobic digestion candidate farms

Farm Type	Number of candidate farms	Energy generation capacity (MW)	Potential annual energy generation (MWh/yr)
Dairy	5,596	804	6,431,527
Swine	2,645	863	6,802,914
Total	8,241	1,667	13,144,441

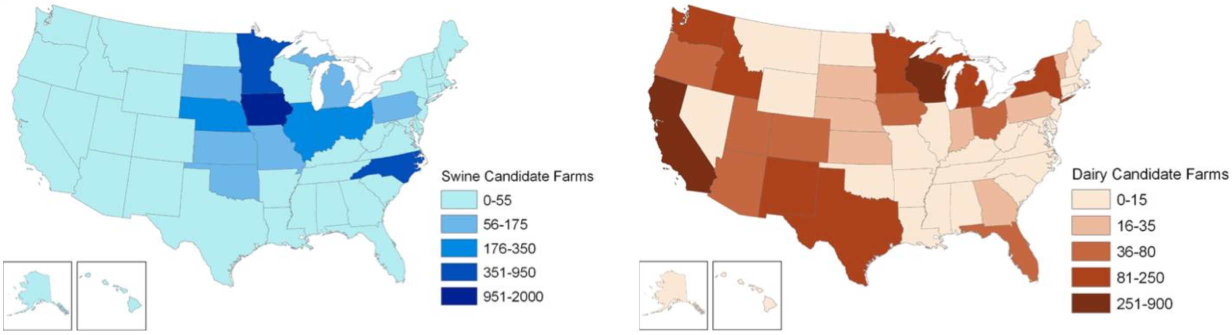

Fig. 19: Geographical spread of U.S. anaerobic digestion candidate farms (AgSTAR, undated)

A major barrier to the implementation of farm anaerobic digestion in California is the capital cost. AgSTAR suggests the capital costs of farm anaerobic digesters decreases with farm size regardless of whether the type of systems implemented is plug flow, covered lagoon, or complete mix. Chris Voell identified additional challenges associated with manure digestion in the US. Amongst the challenges are:

- The lack of financial incentives in the form of renewable energy tariffs.
- Interconnection costs that can be as high as $500,000 that makes small scale digesters unviable.
- Fluctuating energy prices that affect the competitiveness of renewable energy.
- Access to capital incentives.
- Permitting and regulatory restrictions. For example, in Califnornia there are restriction zones for air emissions from energy generation equipment that mean biogas cannot be burnt.

In addition to on-farm anaerobic digestion plants, it is anticipated the number of anaerobic digestion plants that treat Municipal Solid Waste will increase in California. Ken Decio is a Senior Integrated Waste Management Specialist at the Department of Resources, Recycling and Recovery (CalRecycle). Ken explained that currently there are no commercial stand alone anaerobic digestion plants in California that use MSW as feedstock. Anaerobic Digestion of MSW is currently completed at Wastewater Treatment plants, such as the East Bay Muncipal Utilities Main Wastewater Treatment plant in Oakland that co-digests food waste with primary and secondary wastewater. Ken explained that following publication of the Climate Change Scoping Plan for California, CalRecycle has been set a target to reduce the amount of biodegradable MSW landfilled each year by 50 % (i.e. by 14 million tons) by 2020. It is anticipated to meet this target 3.5 million tons of MSW would be diverted to approximately 70 anaerobic digestion plants. It is anticipated the annual amount of electricity produced by these plants would be in the region of 500 million MWh. Ken highlighted several key factors are involved in the realisation of this target, including:

- Introduction of mandatory food collection schemes.
- Restriction of organic material disposal to landfill.
- Increased tipping fees at landfill and compost facilities.
- Increased demand for local renewable energy resources.
- Improvement in anaerobic digestion technologies.
- Public financial support for development of credible financial business models.

6.3 Application of Anaerobic Digestion in Germany

Prof. Dr.-Ing. Frank Scholwin explained the number of anaerobic digestion plants in Germany has been rising since the year 2000, and especially since revisions to the Renewable Energies Act (EEG) in 2004 and 2009 (see section 7.3). The number of anaerobic digestion plants in Germany increased from approximately 1,000 plants with an electricity generating capacity of 80 MWe in 2000, to approximately 4,900 plants with an electricity generating capacity of 1,850 MWe in 2008 (Fig. 20). Prof. Dr.-Ing. Frank Scholwin stated there are now over 6,000 anaerobic digestion plants in Germany.

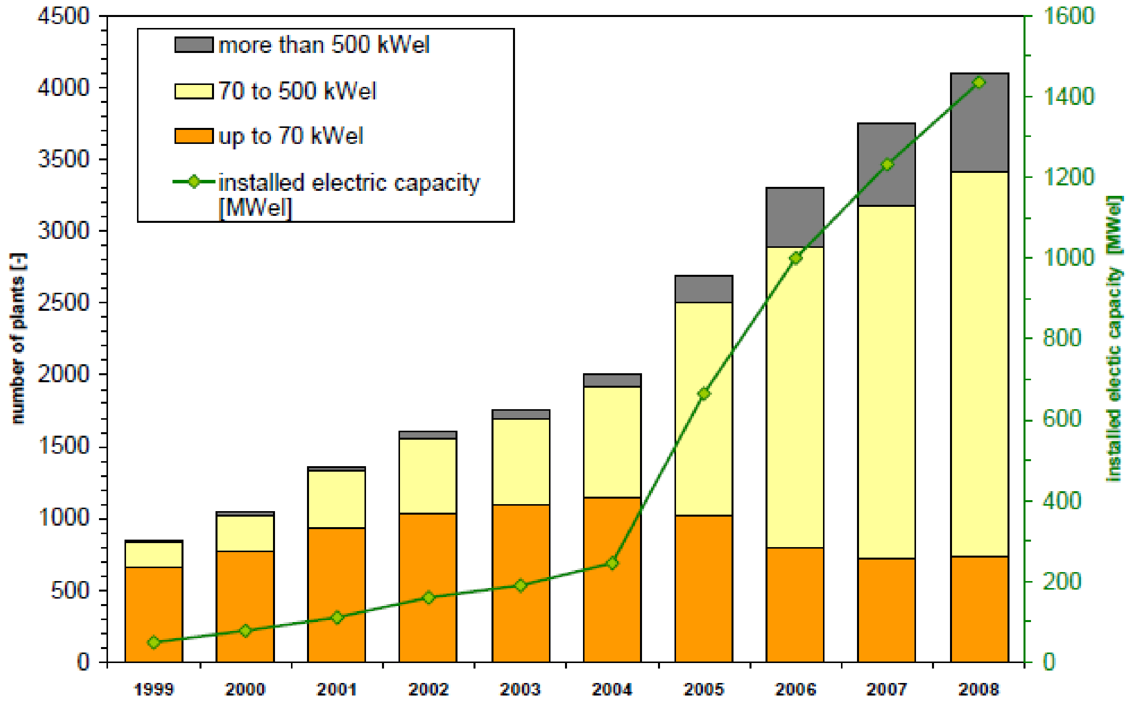

Fig. 20: The number and installed electrical capacity of anaerobic digestion plants in Germany, 1990 – 2008 (Scholwin, 2011).

The number of anaerobic digestion plants built in Germany increased in 2005 and 2006 following revision of the EEG in 2004, which provided higher remuneration for the production of renewable electricity. Prior to the 2004 revision of the EEG Prof. Dr.-Ing. Frank Scholwin explained approximately 200 to 250 anaerobic digestion plants were built per year. This increased to more than 600 plants per year in 2005 and 2006.

Prof. Dr.-Ing. Frank Scholwin explained the principal use of biogas is for the production of electricity in Combined Heat and Power (CHP) units. In 2009 approximately 12 TWh of electricity was produced from the combustion of biogas in Germany, which was an increase of 2.8 TWh on the previous year. Prof. Dr.-Ing. Frank Scholwin suggested between 5.0 TWh and 5.7 TWh of heat produced from the combustion of biogas was used in 2009.

Prof. Dr.-Ing. Frank Scholwin explained anaerobic digestion plants in Germany were most concentrated in Bavaria, Lower Saxony, and Baden-Wüttemberg in 2009 (Table 5).

Table 5: Distribution of anaerobic digestion plants in Germany in 2009

State	Number of anaerobic digestion plants in operation	Total installed electrical capacity (MW)	Average plant electrical output (kW)
Baden-Wüttemberg	612	161.8	264
Bavaria	1,691	424.1	251
Berlin	0	0	0
Brandenburg	176	112.0	636
Bremen	0	0	0
Hamburg	1	1	1,000
Hesse	97	34.0	351
Mecklenburg-Western Pomerania	215	116.9	544
Lower Saxony	900	465.0	517
North Rhine-Westphalia	329	126.0	383
Rhineland-Palatinate	98	38.5	393
Saarland	9	3.5	389
Saxony	167	64.8	388
Saxony-Anhalt	178	113.1	635
Schleswig-Holstein	275	125.0	454
Thuringia	140	70.3	502
Total	**4,888**	**1,856**	**380**

(Scholwin, 2011)

Prof. Dr.-Ing. Frank Scholwin explained the mean size of the anaerobic digestion plants built in Germany between 2000 and 2004 was 300 kWe. The mean size of anaerobic digestion plants built in Germany between 2005 and 2008 was higher at 500 kWe due to the introduction of higher subsidies under the EEG (including the introduction of a cogeneration bonus and renewable biogas plant bonus). The latest revision of the EEG in 2009 supported the production of biogas by smaller anaerobic digestion plants, and consequently the mean anaerobic digestion plant size fell to 335 kWe for 2009 and 2010.

The main feedstock's used in German anaerobic digestion plants are biogas crops (e.g. maize) and animal manures on a mass basis. The predominant source of energy from anaerobic digestion plants in Germany is biogas crops (Fig. 21). This is because manures are associated with relatively low biogas yields when compared to biogas crops. Stefan Thurner (Institut für Landtechnik und Tierhaltung) highlighted that in Bavaria (the state with the largest number of anaerobic digestion plants) 48.8 % of anaerobic digestion plants use maize silage as feed, whilst grass silage in the substrate mix accounts for 10.3 %. Stefan suggested the use of grassland for biogas production will become more important in the future because of a declining cattle population and the need to preserve permanent grassland.

Dr. Birgit Vollrath (Bavarian Landesanstalt für Weinbau und Gartenbau Veitschöchheim) is investigating the potential to use wild-type plants as feedstock for anaerobic digestion. In addition to providing a source of biomass, the cultivation of wild-type plants provides the opportunity to add new species to the agricultural landscape. Birgit suggested the use of wild-type plants could improve the image of the energy farmer and anaerobic digester operator. Birgit suggested additional advantages of wild-type crops over maize crops included:

- The crops only need to be planted once every five years as opposed to annually. This means the soil will be compacted less and the risk of erosion will be reduced.
- No pesticides are needed.
- Labour input per year is lower.
- Lower fertiliser input.

Birgit is currently conducting research to identify the best seed blend to attain maximum biomass yields whilst maintaining low labour and cost inputs. To date Birgit has tested 12 seed blends. To date the biogas yields obtained from the wild-type plants has been lower than for maize silage because biomass was lignified. The blends have since been modified and Birgit expects higher biogas yields for the forthcoming harvest of biomass.

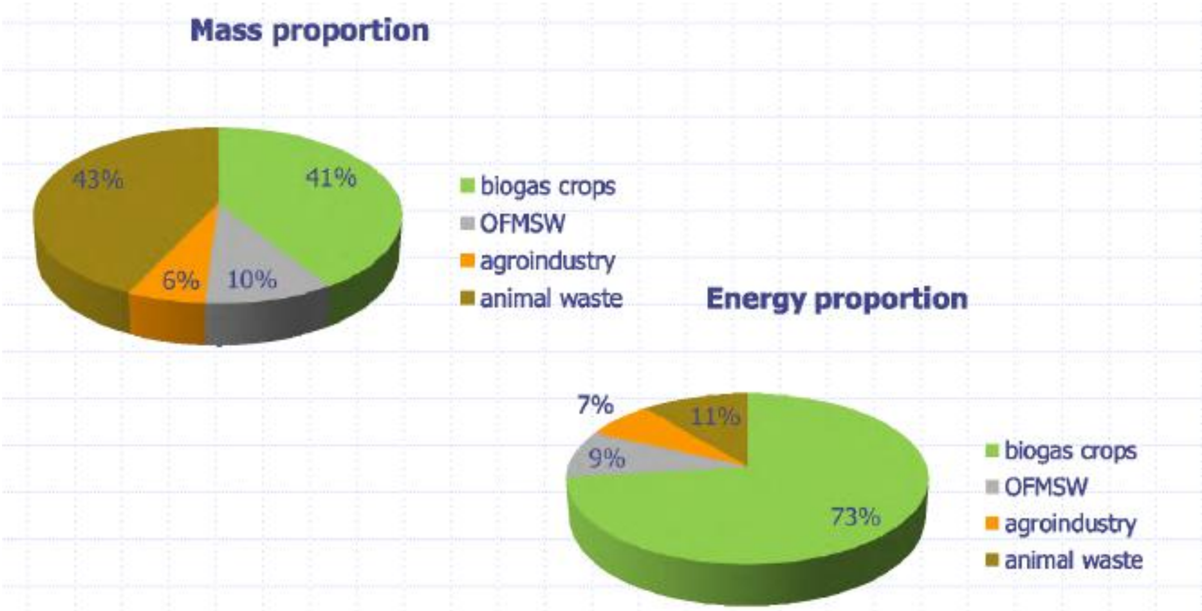

Fig. 21: Main substrates for biogas production in Germany (German Bioenergy Research Centre, 2010)

7.0 Anaerobic digestion relevant policy

7.1 UK Policy

In addition to the targets detailed in Section 3.0 of this report, UK policy that is driving forward the implementation of AD in the UK centres on financial incentives that were introduced as a consequence of the Energy Act 2008. These are namely the renewable electricity Feed-In Tariff (FITs), Renewable Heat Incentive (RHI) and the Biomethane Injection Tariff.

FITs were introduced in April 2010 with the aim of increasing small scale (less than 5 MW) renewable electricity generation. FITs consist of two payments that are paid for by licensed electricity suppliers. The generation tariff is payable on all electricity generated by a renewable technology, and is dependent on technology type and scale. Originally the generation tariff for anaerobic digestion was set at:

- 11.5 p/kWh for anaerobic digestion plants with installed electrical capacities of less than 500 kW.
- 9.0 p/kWh for anaerobic digestion plants with installed electrical capacities of more than 500 kW.

The Government completed the first review of the FIT and published the outcome of the review on 9th June 2011. The review found that the level of support provided by the generation tariff for small scale anaerobic digestion was not sufficient, and consequently the tariff will be increased as detailed below.

- Anaerobic digestion plants with installed electrical capacities of less than 250 kW will be eligible for a generation tariff of 14.0 p/kWh.
- Anaerobic digestion plants with installed electrical capacities between 250 kW and 500 kW will be eligible for a generation tariff of 13.0 p/kWh.

The second element of payment under FITs is the export tariff that provides renewable electricity generators with a guaranteed minimal price for the electricity they sell to electricity supply companies. This is currently set at 3 p/kWh.

Details regarding the RHI were announced by the UK Government in March 2011. The RHI is the first support scheme for renewable heat in the world. The RHI will be introduced in two phases. Phase one will be introduced in July 2011 and till target the non-domestic sector. This is because the non-domestic sector is considered to be able to provide the vast majority of the renewable heat needed to meet the UK targets. The second phase of the RHI will support the domestic sector and will be introduced in 2012. Generation of heat from the combustion of biogas is eligible under the RHI for anaerobic digestion systems with thermal capacities of less than 250 kW. The RHI also provides support for the upgrading and injection of biomethane into the national gas grid through the introduction of the biomethane injection tariff. The level of tariff provided for biogas combustion and biomethane injection is set at 6.5 p/kWh.

7.2 Californian Policy

The Global Warming Solutions Act 2006, also referred to as Assembly Bill 32 (AB32), was signed by the Governor of California in September 2006. The Act requires the state of California to reduce greenhouse gas emissions to 1990 levels by 2020. In addition to the greenhouse gas targets set in AB32, California also has set a target to supply 33 % of electricity from renewable sources by 2020. Senate Bill 107 obligates investor-owned utilities (IOUs) to increase the amount of electricity they supply from renewable sources to 20% by 2010. This is referred to the Renewable Portfolio Standard (RPS). Publically-owned utilities (POUs) are encouraged, but not obligated, to meet the RPS. The three largest POUs in California have adopted the RPS. These POUs are the Los Angeles Department of Water and Power Irrigation District (LADWP), the Sacramento Municipal Utility District (SMUD), and the Imperial Irrigation Disctict (IID). Valentino Tiangco explained the SMUD aimed to supply 2,600 GWh of electricity from renewable sources in 2010. Of this electricity, approximately 389 GWh would be produced from landfill gas, 56 GWh from biogas produced by wastewater treatment plants, and 2 GWh from dairy farm anaerobic digesters. SMUD is currently working with two dairy digesters to generate renewable electricity:

- The Cal Denier Dairy (North Galt) that produces biogas from the slurry produced by 500 cows in a lagoon digester.
- The Tollenaar Dairy (Elk Grove) that produces biogas from the slurry of 1,000 cows in a complete mix digester.

SMUD aims to expand the amount of electricity it supplies from anaerobic digestion through collaboration with three further anaerobic digestion projects (New Hope Dairy, Warmerdam Dairy, and BLT-Food Wastes).

In 2006 Assembly Bill 1969 authorised the introduction of feed-in tariffs and standard contracts for the purchase of renewable electricity from public water and wastewater facilities with electrical capacities of less than 1.5 MWe. In 2007 this authorisation was extended to include renewable electricity producers other than public water and wastewater facilities. In 2009 the eligible project size was increased to 3.0 MWe. The new law took effect in January 2010, but the feed-in tariff is yet to be introduced. The California Public Utilities Commission that is responsible for introducing the tariff is currently considering significant changes to the program. In its current format the California feed-in tariff would allow eligible customers (customers of Southern California Edison, Pacific Gas and Electric Company and San Diego Gas and Electric Company) to enter into 10, 15, 20 and 25 years contracts with their utility to sell the electricity they produce from renewable technologies at a time-differentiated market price. The prices for 2011 are $0.08846/kWh, $0.09465/kWh, $0.10098/kWh, and $0.10442/kWh for 10, 15, 20, and 25 year contracts, respectively.

7.3 German Policy

The Electricity Feed Act was introduced in 1991 as the first remuneration system for renewable electricity production in Germany. The Act required electricity grid operators to purchase renewable electricity from producers and to pay 14 pfennings/ kWh for it. This was increased to 15 pfennings/ kWh when the Act was amended in 1994. There were approximately 400 anaerobic digesters in Germany in 1998, which were predominantly built on animal farms. These digesters tended to be smaller with electrical outputs of 50 kW to 60 kW.

The Electricity Feed Act was surpassed by the introduction of the Renewable Energy Act (EEG) in 2000. The EEG increased the remuneration rate to 20 pfennings/ kWh for plants with electrical capacities of up to 500 kW. Since its introduction the EEG has been revised in July 2004, June 2008 and January 2009. The 2004 revision resulted in a significant increase in the amount of electricity produced from biomass. In 2009 the EEG specified a basic renewable electricity tariff that ranged between 0.1167 and 0.0779 €/kWh (dependent on plant size). The 2009 revision led to further electricity and cogeneration production from biogas. Anaerobic digestion plants are able to claim this tariff for a period of 20 years. The EEG also specified a number of bonus tariffs as shown in Table 6.

Table 6: Basic and bonus tariffs available under the EEG 2009. Tariffs are shown in units of Cent/kWh

		< 150 kW	< 500 kW	< 5 MW
Basic tariff		11.67	9.18	8.25
Clean air bonus	Old plants	1.0	1.0	
	New plants	1.0	1.0	
Renewable primary products bonus (new plants)		7.0	7.0	4.0
Landscape work bonus (new plants)		2.0	2.0	
Bonus for use of manure (new plants)		4.0	1.0	
Bonus for innovative technologies (without gas injection into the grid)		2.0	2.0	2.0
Bonus for innocative technologies (Gas injection)	New plants	Depending on the size of the gas treatment 1 or 2 Cent/kWh		
	Old plants	2.0		
Combined Heat and Power bonus		0/2/3	0/2/3	0/2/3

(German Biogas Association, 2011)

The Renewable Energies Heat Act was introduced in January 2009. The act places an obligation on owners of newly constructed buildings to use renewable energy to meet 14 % their heat requirements.

The Biomass Ordinance was introduced in 2001. It sets guidelines on:

- What materials are classed as biomass.
- Which technologies can be used to produce power from biomass.

- Which environmental requirements are to be met when producing power from biomass.

With regards to anaerobic digestion, the Biomass Ordinance excludes biogas produced from animal by-products.

The Gas Network Ordinance (GasNZV) places an obligation on gas grid operators to grant preferred grid access to anaerobic digestion plants that have requested access. The regulation requires the grid operator to pay 75 % of the costs of grid access for distances less than 1 km. The anaerobic digestion plant operator must fund the remainder up to a maximum of €250,000. Grid access is comprised of the connecting pipeline (up to 10 km), the gas pressure metering plant, the compressor and the calibrated measurement plant. Grid access is owned by the grid operator, who must cover the costs of maintenance and operation.

8.0 Permitting requirements

8.1 Permitting requirements in the UK

The regulatory requirements associated with AD vary dependent on a number of factors that include scale, feedstock type and product use. Regulatory requirements may include:

1. A Duty of Care to ensure waste is handled safely and by registered handlers.
2. An Environmental permit or exemption if in England and Wales, which combines the previous Waste Management regulations and Pollution Prevention Controls into a single scheme.
3. In Scotland a Waste Management Licence (if taking waste from other businesses or people) and a Pollution Prevention and Control permit (if plant is treating more than $50m^3$ of waste per day).
4. A Waste Carrier Licence if carrying other peoples waste.
5. An Animal By-products Regulation licence if feedstock may contain animal by-products.
6. Planning consent may be needed. This should be confirmed by contacting the local planning authority.
7. Cross compliance.
8. Health and Safety

8.1.1 Duty of Care

To comply with the duty of care:

- Waste must be transported and stored appropriately and securely so that it does not escape.
- Waste must be transported and handled by people or businesses that are authorised to do so.
- Waste Transfer Notes (WTNs) must be completed to document all waste that is transferred. Records must be kept for at least 2 years.

(NetRegs, undated)

8.1.2 Environmental Permitting (England and Wales)

Many Anaerobic Digestion activities are subject to the Environmental Permitting Regulations 2010 (S12010 No. 675). The Environmental Permitting Regulations were introduced to provide a more streamlined process than the previous Pollution Prevention and Control and Waste Management Licensing Regulations (Anaerobic Digestion Portal, undated). Under the Environmental Permitting Regulations AD operators are required to obtain permits or exemptions for specific activities (Environment Agency, 2010). Exemptions can be obtained for lower risk activities and are normally free of charge, but provide the Environment Agency with information about what is being done at the AD plant. Permits are required for medium and high risk activities and contain rules that must be complied with. Environmental permits are either ‘standard’ or ‘bespoke’. Table 7 details the main authorisations that are applicable to AD plants.

Table 7: Main authorisations likely to apply to AD processes (Environment Agency, 2010).

Activity	Type of authorisation needed
Anaerobic Digestion (excluding sewage treatment works)	
Anaerobic Digestion at premises used for agriculture and burning of resultant biogas: • Waste types are plant tissue, manures and slurries. • The biogas burner on the AD plant must have a net rated thermal input of less than 0.4MW. • The waste must remain in the AD plant for a minimum of 28 days. • Up to 1,250m^3 of waste can be stored or treated at any one time.	Registered non-chargeable exemption from permitting – Exemption T24.
Anaerobic Digestion at premises not used for agriculture and burning of resultant biogas: • Waste types include manures, plant tissue, animal tissue, and biodegradable kitchen and canteen waste. • The biogas burner on the AD plant must have a net rated thermal input of less than 0.4MW. • The waste must remain in the AD plant for a minimum of 28 days. • Up to 50m^3 of waste can be stored or treated at any one time.	Registered non-chargeable exemption from permitting – Exemption T25.
Anaerobic Digestion of waste for the purpose of recovery at premises used for agriculture. Storage and treatment of more than 1,250m^3 of manures, slurries and plant tissue for the purpose of recovery. Includes on-site storage of waste digestate.	Environmental permit for a waste operation. Standard rules environmental permit SR2010 No. 16 subject to certain limitations.
Anaerobic Digestion of waste for the purpose of recovery. Storage and treatment of more than 50m^3 of biodegradable waste for the purpose of recovery. Includes on-site storage of waste digestate.	Environmental permit for a waste operation. Standard rules environmental permit SR2010 No.15 subject to certain limitations.
Anaerobic Digestion for the purpose of disposal (less than 50 tonnes per day and not including more than 10 tonnes per day of animal waste).	Environmental permit for a waste operation.
Anaerobic Digestion for the purpose of disposal (more than 50 tonnes per day).	Environmental permit for a waste installation.
Anaerobic Digestion of animal waste (not manures or slurries) for the purpose of recovery or disposal (more than 10 tonnes per day).	Environmental permit for a waste installation.
Manufacture of solid fuel from digestate using heat.	Environmental permit for a waste installation.
Biogas combustion	
Burning biogas as a fuel in any appliance with a rated thermal input of 3MW or more	Environmental permit for an installation.
Combustion of biogas as a fuel in any appliance with a net rated thermal input of between 0.4 and 3MW.	Environmental permit for a waste operation.
Combustion of biogas as a fuel in engines at a sewage treatment works with a net rated thermal input between 0.4 and 3MW.	Environmental permit for a waste operation. Standard rules environmental permit SR2009 No.4 subject to certain limitations.

Storage and spreading of digestate	
Storage of waste digestate prior to recovery	Environmental permit for a waste operation. Standard rules environmental permit SR2010 No.17 subject to certain limitations would apply if storing away from the AD plant.
Storage and spreading of waste digestate on agricultural land for agricultural benefit at a rate of up to 250 tonnes/hectare/year.	Environmental permit for a waste operation. Standard rules environmental permit SR2010 No.4 mobile plant for landspreading subject to certain limitations.

8.2 Permitting requirements in California

Valenino Tiangco identified permitting as a major challenge to anaerobic digestion in California. This is because of difficulties in obtaining permits due to the existence of arduous and complex permitting processes. The California Energy Commission is currently proposing a new planning and permitting program for renewable energy in California that would provide local governments with assistance in the planning and permitting process. The overall aim would be to help local governments to evaluate and expedite renewable energy development in their jurisdictions. One of the main problems associated with the current planning and permitting process for anaerobic digestion in California is a lack of an integrated regulatory framework. Currently many agencies use existing frameworks to regulate anaerobic digestion, which are not always appropriate. For example, the California Public Utilities Commission has policies on the financial incentives available. In contrast water agencies don't have specific rules relating to anaerobic digestion, but do have concerns about the water quality impacts of dairy lagoons. This means that currently anaerobic digestion applications are dealt with on a case by case basis, hence leading to an arduous and complex planning process.

The greatest challenges associated with anaerobic digestion permitting and regulation in California centres on water quality and air quality.

8.2.1 Water Quality

The State Water Resource Board (SWRB) is responsible for protecting the state's water resources. Nine Regional Water Boards (RWBs) action the regulatory directives of the SWRB, but each region set its own standards. Most dairy farms in California are concentrated in the Central Valley and are consequently regulated by the Central Valley Regional Quality Water Board.

The federal Clean Water Act 1972. The Clean Water Act 1972 aims to eliminate pollutant discharges into watercourses. Anaerobic digestion developers must obtain permits from state environmental agencies to enable them to discharge polluted water into surface water.

The main challenges associated with anaerobic digestion and water quality in California are concerns that:

- The co-digestion of off-site waste (e.g. food waste) with animal slurries will increase the salt concentration (including Na^+, K^+, and Cl^-) and nitrate content of digestate.
- Lagoons do not safely contain digestate.
- There is potential for groundwater quality impacts from the form and concentration of nitrogen stored in anaerobic digestion lagoons.

The latter two points can be addressed through design of anaerobic digestion plants, but the concerns regarding salt and nitrate concentration are less easily resolved and currently mean than on-farm digesters are limited to the use of animal slurries. The Board is concerned with the salt concentrations associated with co-digestion because surface and groundwater in California has increased levels of salinity due to the state's arid climate, importation of water, and large agricultural industry. The anaerobic digestion of animal slurries produces digestate with predictable salt levels. However, when other feedstocks are used for co-digestion with manure the salt concentration of the digestate is unpredictable and hence application to land could further increase the salinity of surface and groundwater.

8.2.2 Air Quality

The California Air Resources Board (CARB) regulates mobile and stationary sources of air emissions according to the federal Clean Air Act 1970. CARB is responsible for providing guidance and monitoring the activities of 35 local air districts within California in relation to stationary air emissions. The Clean Air Act establishes National Ambient Air Quality Standards (NAAQS's) for six pollutants. CARB sets State standards for these pollutants. Table 8 shows California has adopted stricter AAQS's compared to the national standards. The Clean Air Act presents a major challenge to the development of dairy anaerobic digesters in California. This is because when methane is burnt to produce energy nitrous oxides are produced. To maintain emissions below those set by CARB the technology that would need to be employed by a dairy digester would prove the development to be economically unviable.

Table 8: National and California State Ambient Air Quality Standards

Pollutant	Averaging time	California State Standard	National Standard
Ozone	1 hour	0.09 ppm	
	8 hours	0.07 ppm	0.075 ppm
Carbon monoxide	1 hour	20 ppm	35 ppm
	8 hours	9 ppm	9 ppm
Nitrogen dioxide	1 hour	0.18 ppm	0.100 ppm
	Annual average	0.030 ppm	0.053 ppm
Sulfur dioxide	1 hour	0.25 ppm	
	3 hours		0.5 ppm
	24 hours	0.04 ppm	0.14 ppm
	Annual average		0.03 ppm
Respirable Particulate Matter (PM10)	24 hours	50 µg/m^3	150 µg/m^3
	Annual average	20 µg/m^3	
Fine Particulate Matter (PM2.5)	24 hours		35 µg/m^3
	Annual average	12 µg/m^3	15 µg/m^3
Lead	Monthly average	1.5 µg/m^3	
	Quarterly average		1.5 µg/m^3
Hydrogen sulphide	1 hour	0.03 ppm	No National Standard
Sulfates	24 hours	25 µg/m^3	No National Standard

(California Air Resources Board, 2010)

8.3 Permitting requirements in Germany

The minimum requirement for the installation and operation of an anaerobic digestion plant in Germany is a building permit. The permit procedure depends on the scale, location and feedstock of the anaerobic digestion plant. There are two permit options for anaerobic digestion in Germany that are based on the Federal Emission Control Act (BimSchG) and the Federal Building Code (BauGB). The BimSchG aims to control harmful environmental impacts (e.g. air pollution, noise, vibrations). The flow diagram shown in Fig. 22 can be used to identify the permitting requirements for an anaerobic digestion plant.

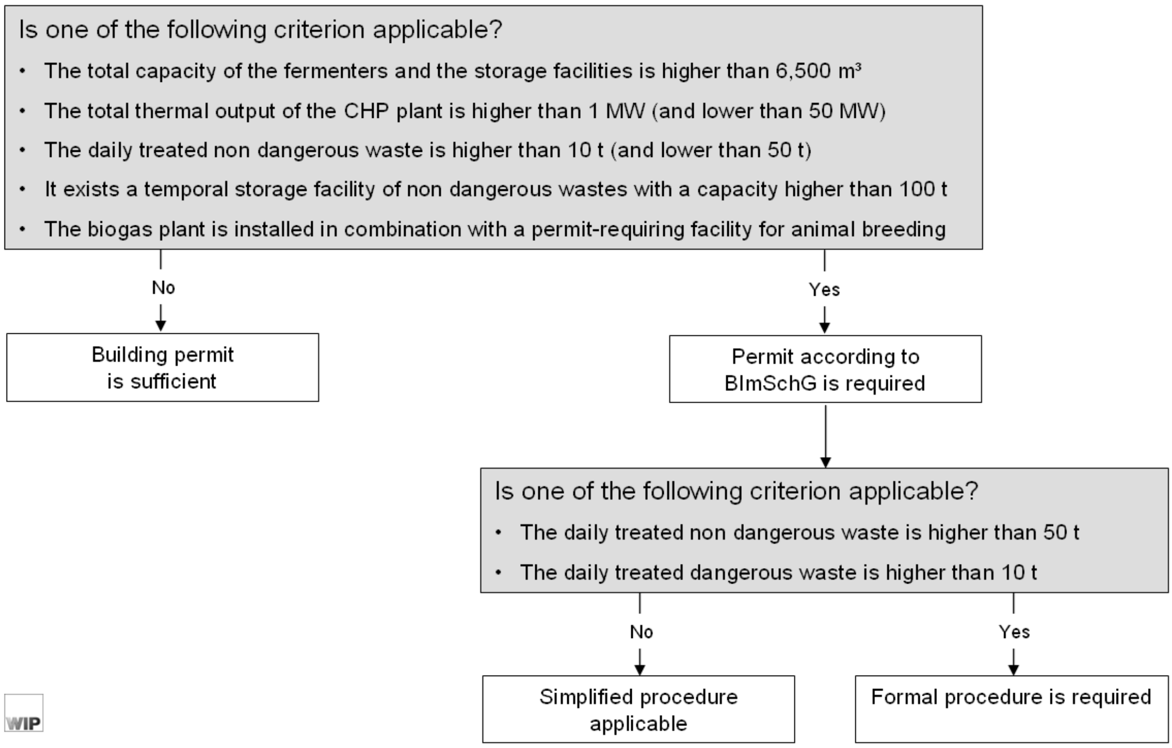

Fig. 22: Flow diagram to determine anaerobic digestion permitting requirements in Germany (Kirchmeyr et al. 2010).

Permitting under the BauGB is usually applicable to smaller anaerobic digestion plants. To determine compliance with the permit the plant must be suitably located and the plant must be permissible with the building regulation that determines how the plant will be installed.

Permitting under the BimSchG is more complex than under the Federal Building Code. However, a permit obtained under the BimSchG automatically includes a permit for building and compliance with Regulation EC/1774/2002 that is concerned with implementing health rules for animal by-products that are not intended for human consumption.

German law recognises that most suitable location for anaerobic digestion plants is in rural areas by requiring plants in rural areas to be permitted, unless they violate public interest. The plants covered by this law must be closely connected to a farm, predominantly receive feedstock from this or neighbouring farms, and the anaerobic digestion plant must have an electrical output of less than 0.5 MW.

In addition to the above permits, legislation must be considered when developing an anaerobic digestion plant. These include:

- Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal.
- Federal Water Act.
- Fertilizer Act.
- Regulations on work safety and safety of operation, fire protection.
- Environmental legislation.
- Legislation on veterinary aspects.

9.0 Funding and finance for anaerobic digestion

Sources of funding for anaerobic digestion plants are similar in the UK, Germany and the California. Funding can be sourced from public funding programs, private debt financing, and equity or working capital from the farm. Normally half the funding for a project must come from the farm and loans from commercial lenders. Private financing can come from:

- Traditional financing in which a loan is granted to a farm by a bank. The farms assets are used as collateral to secure the loan. This is the most common source of private financing. The credit history of the farm is important.
- Project financing in which project funds are granted to the anaerobic digestion project rather than the farm. Project financing is usually used for large scale projects with multiple shareholders. The main criteria used are rates of return.
- Investment funds that combine funds from several small investors, which reduces the risk to each investor.
- Energy contractors, where a contractor is a company that specialises in biogas production.

Alternatively biogas plants or co-generation equipment could be leased from a leasing company. It is common for cogeneration equipment to be leased using a leasing contract.

9.1 UK funding and finance

The main financial support mechanism for anaerobic digestion in the UK is through the FIT and RHI. Following introduction of the renewable electricity FIT grant funding towards the capital cost of renewable energy installations was withdrawn.

9.2 US funding and finance

Philip Brown (Business and Cooperative Loan Specialist at US Department of Agricultural Rural Development) explained the sources of funding available for anaerobic digestion projects in the US through the USDA Rural Development. The USDA Rural Development aims to improve the economy and quality life in rural America. With regards to rural energy generation the USDA Rural Development provides payments, grants, loans, and loan guarantees for the development and commercialisation of renewable energy. Philip explained the Farm Bill 2008 (also known as The Food, Conservation and Energy Act 2008) included 12 energy related financial programs, four of which are administered by the USDA Rural Development. These are:

- *The Biorefinery Assistance Program* that provides loan guarantees of up to $250 million for the development, construction and retrofitting of commercial scale biorefineries. In 2009 the program received 17 applications, 2 projects of which were provided with loan guarantees.
- *The Repowering Assistance Program*, which provides payments to existing biorefineries to replace fossil fuels with biofuels for the production of process heat and power.
- *The Biorefinery Program for Advanced Biofuels*, which provides payments to producers to ensure an expanding production of advanced biofuels.
- *The Rural Energy for America Program (REAP)* that provides loan guarantees and grants to agricultural producers and small businesses to purchase and construct

renewable energy systems and energy efficiency improvements in addition to grants to determine a projects feasibility. The maximum REAP grant available is $500,000, which can be used to finance up to 25% of the cost of a rural energy project. Federal guarantees of bank loans for energy projects are available up to a maximum value of $25 million. The loan can finance up to 75% of the project, and the lender gets a 60-85% guarantee on the loan (dependent on size). REAP grants and guaranteed loans can be combined, but this combination cannot exceed 75% of the project cost. To access REAP funding an anaerobic digestion project must be within a rural area, the applicant must own and control and project site, the project must use commercially available technology and the project must cash flow and operate successfully.

Philip highlighted that the Department of Energy also provides loan guarantees.

9.3 German funding and finance

Good financing opportunities were essential in the development of the German biogas sector. However, good financing opportunities only developed because of:

- The implementation of policies to support development of the sector e.g. the EEG.
- The development of mature and reliable technology.
- Reduced financial risk due to the introduction of stable policies and legislation.

There are several national and regional subsidies and low interest loans that support anaerobic digestion financing in Germany. KFW Bank provides one of the main sources of subsidy at the national level through the provision of low interest loans. Financial support is less stable as the federal state level due to continuous changes in the political framework.

The Market Incentive Programme for renewable energy is a federal government programme that was launched in 2000. The programme provides funding towards the capital costs of biomass plants, including anaerobic digestion. In 2007 and 2008 the programme provided €352 million in grant funding, which was estimated to trigger investments of more than €3.5 billion. In 2009 funding of €470 million was estimated to trigger €3 billion of investment in renewable energy technologies in Germany.

Additional source of financial support for anaerobic digestion in Germany include:

- A loan scheme by the Credit Institute for Reconstruction has assisted in the construction of 1,239 anaerobic digestion plants through provision of interest-reduced loans and partial debt relief.
- The Agricultural Investment and Support Programme that has provided an advisory service and grant funding for anaerobic digestion plants.

10.0 Digestate

Most commonly digestate is used as a fertiliser in the UK, California and Germany. The digestate produced from anaerobic digestion is considered a superior fertiliser compared to the undigested material. This is because the anaerobic digestion process increases the nitrogen availability of the material. Frequently anaerobic digestate is separated into a solid and liquid fraction. The solid fraction is used as a soil amendment, whilst the liquid fraction is used as a liquid fertiliser.

BD Agro Renewables (Germany) explained the concentration of nutrients in liquid digestate is relatively low due to the presence of large volumes of water. This increases operational cost associated with the transport and application of the material to land. To overcome these problems liquid digestate can be dewatered through the use of ultrafiltration and reverse osmosis to produce a more concentrated liquid fertiliser.

In addition to using digestate as fertiliser, BD Agro Renewables suggest solid digestate can be dried and pelleted to produce a solid combustion fuel. The energy content of solid digestate is in the region of 14 MJ/kg, which is slightly lower than the energy content of raw biomass (e.g. miscanthus or wood chip). However, the use of solid digestate as fuel is advantageous because:

- The amount of energy extracted per tonne of anaerobic digestion feedstock is increased as energy is harnessed through anaerobic digestion and combustion.
- Reliance on energy crops is reduced, easing pressure on land for food and fuel production.

Alternatively pelletised digestate can be used as a solid fertiliser. The advantage of pelletising the digestate is that it produces a more stable product that can be stored for longer periods without degradation. There are a number of additional advantages to producing solid digestate fuel pellets, including:

- Increasing the density of the digestate. This reduces transportation costs as more material can be transported per vehicle movement.
- Reduced moisture content as moisture is evaporated during the pelletisation process. Typically the moisture content of pellet is less than 15 %, making the digestate a more stable product.
- Improved fuel combustion handling properties that mean fuel handling will be easier as fuel blockages are less likely to occur.

11.0 Biogas injection into the national gas grid

The injection of biogas into the gas grid is associated with a number of stages that are shown in Fig. 23.

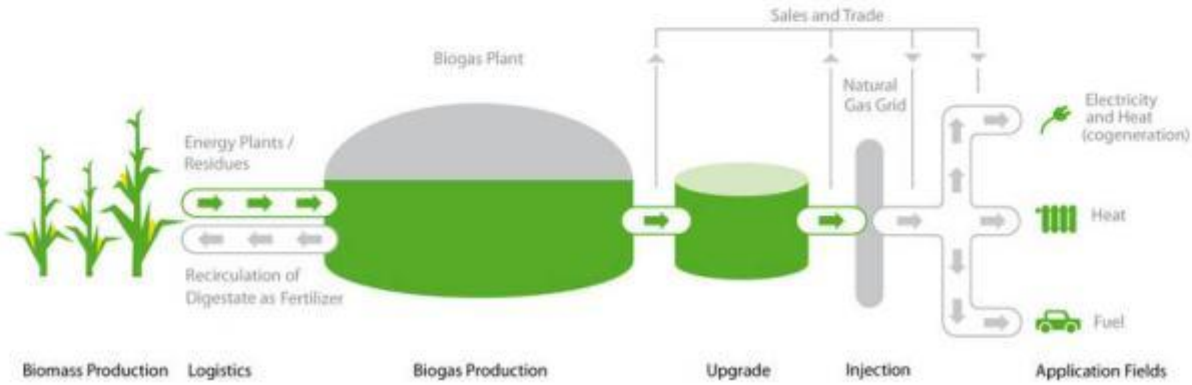

Fig. 23: Stages involved in the production of biomethane (dena, undated)

The biogas produced from anaerobic digestion typically contains between 50 % and 70 % methane, and between 25 % and 50 % carbon dioxide. The biogas also contains smaller proportions of hydrogen sulphide, ammonia and water. Natural gas distributed through the gas grid contains between 85 % and 95 % methane. Consequently the concentration of methane contained in biogas must be increased to produce a product that is referred to as biomethane. This is done by removing carbon dioxide and the minor compounds during biogas upgrading.

Biogas upgrading involves a number of stages:

- Clinging particles are removed through filtration.
- The biogas is dried to remove water.
- Hydrogen sulphide is removed. The most common techniques employed are gas pressure washing and pressure swing adsorption.

Biomethane injection involves:

- Air and LPG (Liquefied Petroleum Gas) conditioning to adjust the Wobbe value and calorific value to meet the specifications of the gas grid. The Wobbe-Index is the gross calorific value of the gas divided by the specific gravity of the gas relative to air at ISO conditions (pressure of 1.01325 bar nd temperature of 0 °C).
- Gas property measurement and calibrated metering to measure the operating volume, pressure, temperature and calorific value of the biomethane. Propane may be added to biomethane to increase the calorific value of the gas injected into the gas grid.
- Gas compression to required grid level.
- Odourising if required.

The advantages of biomethane injection into the gas grid include:

- More efficient use of biogas. Typically the combustion of biogas on-site at anaerobic digestion plants results in 30 % - 35 % of the energy in the gas being harnessed. A relatively low efficiency is achieved because frequently a large proportion of heat has to be vented to atmosphere due to the cost of installing the infrastructure that would be needed to enable the heat to be utilised. If biogas is upgraded and injected into the gas grid it can be used in modern biomass boilers that are associated with efficiencies in excess of 90 %.

- Greater competition for renewable gas as the biogas producer is able to access a larger market than if the biogas is sold and used locally. This potentially increases the financial value of the biogas.

11.1 Biogas injection in the UK

The main participants in the UK gas grid are:

- The Office of Gas and Electricity Markets (OFGEM) that is responsible for financial regulation of the gas and electricity market.
- The Health and Safety Executive that is responsible for protecting against health and safety risks.
- Producers who produce gas that enters the national gas grid.
- Gas Transporters (GTs) who provide the pipelines through which gas is transported. There are three types of GT:
    - The Transmission System Operator (TSO) that owns and operates the high pressure National Transmission System (NTS).
    - The Gas Distribution Networks (DNs) that transport gas from the NTS to the end consumer. The DN pipelines operate at different pressures. There are 8 DNs in the UK.
    - Independent Gas Transporters (iGTs) that install and operate their own pipeline systems e.g. on housing estates.
- Shippers who make arrangements to transport gas through GT pipelines. Shippers contract with producers to bring gas into the gas transportation system.
- Suppliers who sell gas to consumers. The supplier has to have arrangements in place with a shipper to ensure enough gas can be supplied to meet demand.

To physically connect to the gas grid an anaerobic digestion plant must agree with a licensed GT that the GT is willing to operate and own the pipeline connection. In addition to the physical connection a biomethane producers should have a Network Entry Agreement with the GT. This agreement should specify the technical and operational conditions for connecting to the gas network.

The biomethane injected into the gas grid must comply with the gas quality requirements of the Gas Safety (Management) Regulations 1996. The key quality requirements of the regulations are shown in Table 9.

Table 9: Key quality requirements of the Gas Safety (Management) Regulations 1996

	Value
Hydrogen sulphide content	< 5 mg/m^3
Total sulphur content	< 50 mg/m^3
Hydrogen content	< 0.1 % (molar)
Oxygen content	< 0.2 % (molar)
Impurities and water and hydrocarbon dewpoints	The gas should not contain solids and liquids that could interfere with the integrity of operation of the gas network
Wobbe-Index	47.20 – 51.41 MJ/ m^3
Odour	Gas below 7 bar should have a stanching agent added

The first time biogas was injected into the UK gas grid was on the 5th October 2010 by Chesterfield Biogas. The biogas was produced at the Thames Water wastewater site in Didcot, Oxfordshire. On the 8th October 2010 Adnams Brewery (Southwold) was the second plant to inject biogas into the national grid. The biogas was produced from the anaerobic digestion of brewery and food waste.

The Green Gas Certification Scheme was launched on the 3rd March 2011 with the objective of tracking the commercial transactions of biomethane through the supply chain. Once a licensed gas supplier registers a sale of biogas to an end-consumer, the Green Gas Certification Scheme issues a Green Gas Certificate in the consumers name. The certificate guarantees the authenticity and origin of the gas supplied to the consumer.

11.2 Biogas injection in California

As in the UK, the upgrading of biogas to produce a renewable gas that can be injected into the gas grid is receiving significant interest but limited application. However, the California Bioenergy Working Group estimates biogas could replace 16% of the natural gas used in California via a renewable gas pipeline.

The first Californian manure digester to upgrade biogas to biomethane for injection into the gas grid was located at Vintage Dairy (Riverdale). This dairy produces biogas from the anaerobic digestion of dairy slurry produced by 5,000 dairy cows using a lagoon digester. Previously the biogas was flared, but since March 2008 the biogas is upgraded to biomethane and injected into the gas grid.

In February 2011 biomethane, produced from the anaerobic digestion of wastewater, was injected into the gas grid. This was the first wastewater anaerobic digestion facility to do this in California. The project is a collaboration between the Southern Californian Gas Company and the city of Escondido. The project is a demonstration project that aims to demonstrate biomethane that is produced from the anaerobic digestion of wastewater can cost-effectively be produced and injected into the gas grid. There are plans for further wastewater anaerobic digestion plants in California to upgrade the biogas they produce for grid injection. This includes the Port Loma Wastewater Treatment Facility in San Diego that expects to begin injecting biomethane into the gas grid by the end of 2011.

11.3 Biogas injection in Germany

Germany aims to meet 6 % of its gas demand from biogas by 2020, increasing to 10 % by 2030. The first two anaerobic digestion plants to inject biomethane into the gas grid in Germany were put into operation in 2006. This increased to 52 plants in 2011. It is anticipated over 100 plants will feed-in to the gas grid by the end of 2011 increasing to 121 by 2013. The expected growth is due to introduction of the GasNZV regulations. The implementation of German biogas injection plants is expected to vary across the German federal states due to differences in political frameworks and the type of agriculture conducted in each state. The most plants are expected to be built in Lower Saxony, Bavaria, and North Rhine-Westphalia (Fig. 24).

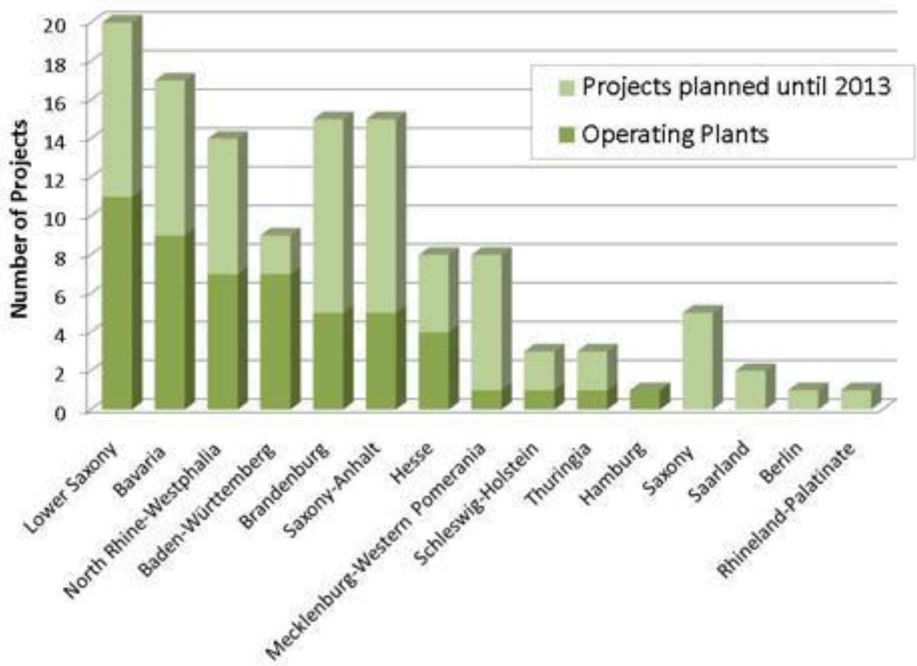

Fig. 24: Projected and operational German biogas feed-in plants by federal state (Dena, undated)

There are two different qualities of gas supplied by German gas grids that must be kept separate: H-gas anf L-gas. Classification between these two types of gas is according to DVGW-Arbeitsblatt 260, which sets out guidelines for gas quality with regards to fuel characteristics and contents of components and additives. The primary difference between H-gas and L-gas is the fuels Gross Wobbe-Index. L-gas is associated with a Gross Wobbe-Index of between 10.5 kWh/m^3 and 13.0 kWh/m^3, whilst H-gas has a Gross Wobbe-Index of between 12.8 kWh/m^3 and 15.7 kWh/m^3. The Gross Calorific Value (GCV) of both classes of gases should be between 8.4 kWh/m^3 and 13.1 kWh/m^3. The supply of H-gas and L-gas in Germany varies geographically.

Unlike renewable electricity, the price of grid-injected biomethane is not guaranteed and depends on the current market price.

A biomethane trading company usually coordinates the transport and sale of biomethane. The trading company enters a number of contractual relationships, as illustrated in Fig. 25.

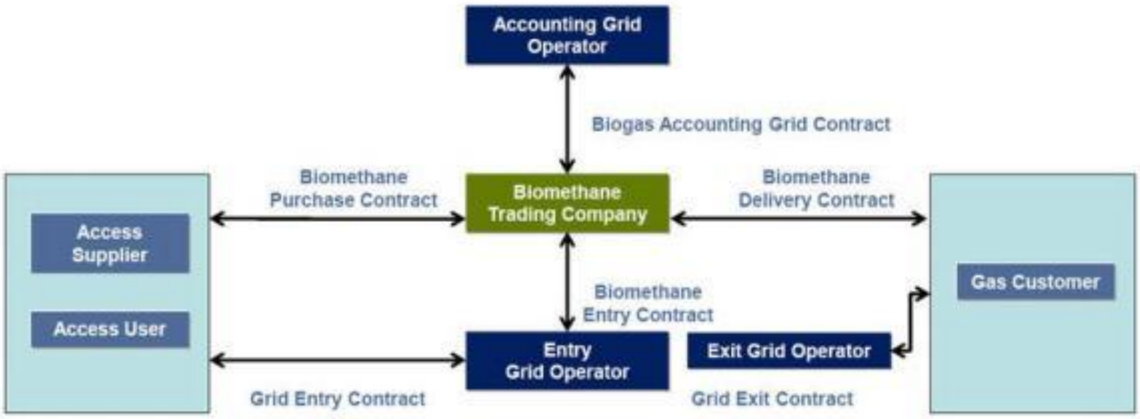

Fig. 25: German biomethane sale and trade contractual relationships (Dena, undated)

The trading company enters a biomethane purchase contract with the biomethane supplier and a biomethane delivery contract with the gas customer. In addition the biomethane trading company enters into a Biogas Grid Accounting Contract with the accounting grid operator. The grid operator balances the amount of biomethane fed into and withdrawn from the gas grid and settles surplus and shortage quantities with the transport client. The biomethane supplier must enter into a Grid Entry Contract with the entry grid operator in order to be allocated to an accounting grid. The gas customer enters into a Grid Exit Contract with the exit grid operator.

12.0 Conclusion

In conclusion development of the German anaerobic digestion sector has been supported by the Renewable Energies Act that provides financial incentives for the application of anaerobic digestion, in addition to a simple permitting and regulatory process. In contrast the anaerobic digestion sector is underdeveloped in California due to a lack of financial support and due to complicated, strict and arduous permitting requirements/ processes. Whilst the anaerobic digestion sector is also underdeveloped in the UK, recent developments that include the introduction of the renewable electricity Feed-In Tariff and simplified permitting procedures should support development of the sector to help it fulfil its potential.

13.0 References

AgSTAR (undated) Operating Anaerobic Digester Projects. [On-line] http://www.epa.gov/agstar/projects/index.html Accessed 14th June 2011

Anaerobic Digestion Portal (undated) Biogas Plant Map [On-line] http://www.biogas-info.co.uk/index.php/ad-map.html Accessed 10th June 2011

California Air Resources Board (2010) Ambient Air Quality Standards. [On-line] http://www.arb.ca.gov Accessed 13th June 2011

Dena (undated) From Biomass to Biomethane – Overview. [On-line] http://www.biogaspartner.de/index.php?id=10062&L=1&fs=2%2Ftrackback Accessed 10th June 2011

Environment Agency (2010b) T24 – Anaerobic Digestion at premises used for agriculture and burning of resultant biogas. Accessed 14th June 2011 at http://www.environment-agency.gov.uk/static/documents/Business/T24_exemption.pdf

German Biogas (2011) The Development of the German biogas sector. Proceedings of the 20th Annual German Biogas Association Conference and Trade Fair. 11th – 13th January 2011

Kirchmeyr, F., Wellinger, A., Hahn, H., Ferber, E., Rutz, D. (2010) Permitting procedures for biogas projects Germany. [On-line] http://www.biogasin.org/files/pdf/Biogas_permitting_in_Germany.pdf Accessed 10th June 2011

NetRegs (undateda) Accessed 14th June 2011 [On-line] http://www.netregs.gov.uk/netregs/63197.aspx

Nettie Drake (2010) Agricultural biogas production – Fiscalini Farms project experience. Presentation at Biogas USA, 13th – 14th October 2010.

Scholwin, F. (2011) Experience with EEG 2009 – conclusions for further development. From Proceedings of the 20th Annual Biogas Conference and Trade Fair. Nuremberg. 11th – 13th January 2011