Consultation on a Bioenergy Action Plan for Wales - February 2009

Response from the Wales Centre of Excellence for Anaerobic Digestion

The Wales Centre of Excellence for Anaerobic Digestion (AD) welcomes the aims of the Welsh Assembly Government to use bio-energy to reduce emissions of greenhouse gases (GHGs), contribute to fuel security, ensure that the public sector leads by example, encourage the development of sustainable forestry and agriculture, and support business development and job creation in all parts of the biomass energy supply chain. Anaerobic digestion and biogas utilisation installations can contribute to all these aims. AD aids achieving multiple government targets by producing a secure supply of renewable energy and non-fossil fuel fertiliser, whilst at the same time reducing waste and agricultural methane emissions. All these are able to make a significant contribution to the reduction of GHG emissions as well as contributing to economic development.

Anaerobic digestion is a well-proven renewable energy and waste management technology. It is widely deployed in many countries, both developed and developing. Germany for example has over 4500 AD installations and hopes to increase significantly this amount; expecting at least 10% of its grid gas supplied from biomethane by 2030. In India, at least 3 million family size digesters exist. China has several times more and has plans to increase the number of plants significantly.

AD technology has shown in many countries (e.g. Germany, Austria and Sweden) to be able to deliver significant environmental, socio and economic benefits such as effective treatment of wastes and wastewaters, reduction of emissions, provision of a source of renewable energy i.e. electricity, heat and transport fuels and has contributed to rural diversification, local employment and attraction of additional income. Biogas plants require specialised equipment related to preparation and supply of feedstocks, maintenance of an adequate biochemical environment for digestion, biogas cleanup and use, as well as preparation of a marketable digestate, which is an important soil conditioner and fertiliser. There is therefore a great potential for increased employment and expertise in the region.

As an example, the biogas industry in Germany in 2006 was estimated to employ around 10,000 people and was worth over €1billion to the German economy. The German Biogas Association predicted that by 2020 AD will either contribute 17% of total electricity produced, or 20% of the natural gas consumption or 35% of the transportation fuel. A mixture of these 3 scenarios will most likely take place. Employment is then expected to be around 85,000 and turnover of €18 bn. The biogas/biomethane sector is booming in Germany, and has become the continent's fastest renewable energy sector. According to the Leipzig report on biogas, a Europe-

wide biomethane-feed-in strategy will result in the creation of 2.7 million new jobs within the EU. Employment will be generated mainly in agriculture and in the manufacture, construction and management of biogas plants and biogas purification plants.

The Water Industry in the UK already has a well established system of AD plants for the treatment of sewage sludge. Indeed, a plant was built in the UK back in the 19th century to treat sewage sludge and produce energy. AD treats approximately 66% of the country's sewage sludge. There are plans to generate 0.8 TWh/yr of electricity from AD by 2010. Anaerobic digestion is, however, still under deployed within the UK waste and farming sectors. In these sectors implementation of AD technology is still in its infancy in the UK. Wales like in most regions in the UK has a long way to go before achieving the implementation of most of the capacity. The financial incentive (currently at 2 ROCs/MWh) provided for renewable electricity generated from biogas coupled with the need to divert biodegradable materials from landfills provided an important platform for the implementation of AD technology in the UK and it has meant that the technology is now in a strong position to be implemented in Wales and indeed in the UK.

In the last couple of years, there have been in addition to the financial incentives, developments in the waste and energy related policies and regulations which are further supporting the removal of barriers to the deployment of AD plants in the UK. The UK government has set itself a legally binding target of meeting 15% of the UK's total energy requirements by 2020 from renewable sources and AD will certainly play a significant role. Recently, the Environment Minister Jane Kennedy announced that "The generation of biogas from the nation's food waste, farm waste and sewage sludge could contribute up to 7.5% of the renewable energy needed to hit UK targets in 2020."

Life cycle analysis of AD systems have concluded that these are best environmental options as compared to composting for treatment of organic wastes and that biomethane as a biofuel for transport saves considerably more GHG emissions than either the first generation liquid biofuels for transport, bioethanol or biodiesel. The treatment of agricultural residues helps to reduce GHGs such as methane and nitrous oxide, digestate is more homogeneous than animal slurries, promotes better hygiene in relation to safe treatment of animal by-products, can aid nutrient control and provide better recycling of nutrients (N, P and K) back to the soil.

It is worth referring the recent specific support provided by WAG in order to increase the deployment of AD in Wales:

- defined AD the best environmental option for treatment of food wastes and suitable organic commercial and industrial wastes
- waste management policy refers that the production and use of digestate (like compost) contribute to recycling targets
- support to Local Authorities for separate collection of municipal food wastes prior to AD
- established a ring fenced capital and revenue financial support package which will be available to local authorities who wish to adopt AD technology
- intended support to local authorities for recovering additional energy from the residual waste via mechanical biological (i.e. AD) treatment plants

- established a Planning Task Force which will work with Planning Authorities to accelerate the Planning Application process
- MAP Capital support for AD facilities treating commercial and industrial wastes
- funded partially the Wales Centre of Excellence for AD (from April 2008)

The Wales Centre of Excellence for Anaerobic Digestion has included here a brief on the developments around Europe as well as in the UK related to the AD sector. The Centre in this response highlights some further needs for a more effective deployment of the technology and suggests areas that WAG should consider and encourage developments, in order for AD to play a larger role in meeting the aims of the Bioenergy Action Plan for Wales.

Background to the Wales Centre of Excellence for Anaerobic Digestion Project

The Wales Centre of Excellence for Anaerobic Digestion is a project developed and implemented by academic and research staff at the Sustainable Environment Research Centre (SERC) at the University of Glamorgan, Wales (http://www.glam.ac.uk/serc). The Wales Centre of Excellence for Anaerobic Digestion role is to expand knowledge and expertise in AD related supply chain and to help address the barriers for a rapid and successful deployment of AD and biogas utilisation facilities in Wales. The Centre offers technical and informational services associated with all aspects of the development and operation of AD and biogas utilisation facilities in Wales (http://www.walesadcentre.org.uk).

Information & Dissemination Services	Technical Support Services
• General project development advice • Public liaison/consultation • Identification of best practice • Dissemination of best practice • Policy and standards development support • Supplier/contractor information • Future technology development • Bespoke training for plant operators, regulators, planners and financial institutions	• Substrate and digestate analysis • Digestibility trials • Laboratory and pilot scale work • System diagnostics • Digester ‘health’ checks • Process control and optimisation • Monitoring, modelling and data capture • Procurement support - tendering advice • Independent design review • Plant commissioning and start-up

The current support to the AD Centre has been insufficient to accommodate all the needed support from stakeholders. Since October 2008 the Centre has provided assistance to over twenty companies considering developing AD schemes. Specific laboratory analytical studies have been undertaken for a quarter of these companies as schemes move forward into the design and financing stages. The AD Centre is also supporting procurement activities of Welsh Local Authorities. In the last year, the Centre has supported a variety of activities namely the development of the PAS 110, contributed to the standard environmental permits and supported the MAP AD Capital competitions. In addition, the Centre has completed four industry collaborative R&D projects aimed at addressing specific technical issues.

The AD Centre has prepared and delivered various events namely: a workshop to showcase AD technologies and use of end-products (over 100 UK wide delegates attended) with a panel discussion on technical, policy/regulatory, environmental and economical assessment of AD; another workshop targeted at local government was attended by the majority of the 22 Local authorities. One more event will take place at the end of June 2009 and is directed at planners in order to raise awareness of the technology, its benefits, current policies and regulations and conclude on potential needs for a faster planning process. A training event for AD plant operators is being prepared and will take place early 2010.

With four decades of experience in AD technology, SERC's R&D work encompasses wastes/biomass/digestates characterisation, biomass pre-treatment stages, reactor design and operation, monitoring and control for AD systems, utilisation technologies for biogas, as well as life cycle analysis. SERC's team is highly multidisciplinary. Furthermore, SERC facilities are extensive in terms of advanced analytical equipment, laboratory and pilot scale reactor systems as well as state of the art on-line monitoring and control solutions that have been specifically tailored for AD processes.

SERC members have participated in a number of large national and international collaborative projects in the field of biological waste treatment funded through EPSRC, DTI Bio-wise, BBSRC LINK, EU Framework Programmes, EU Marie Curie Fellowships, ARC and Carbon Trust. SERC was involved in the management of the EPSRC's Anaerobic Pilot Plant Facility from 1986 to 1994. SERC is a member of the SUPERGEN Sustainable Hydrogen Energy Consortium researching the generation, use and sustainability of bio-hydrogen and biogas from energy crops, the SUPERGEN BioFuelCells Consortium, TSEC-BIOSYS consortium and had two bio-hydrogen and biogas related FP6 projects i.e. REMOVALS and 3 Marie Curie Fellowships. SERC has developed projects with UK Water Companies.

The Centre has well equipped laboratories for the study of waste treatment processes and the production of gaseous biofuels with a range of pilot scale facilities including two pilot plants for the production of biohydrogen and biogas from biomass crops (ESPRC funded and located at IBERS) and flour milling co-product (Premier Food, Barry) and the Renewable Hydrogen Research and Demonstration Facility at Baglan Energy Park. SERC's laboratory has dedicated analytical facilities for bio-process monitoring including GC (with automated headspace, SPME), LC/MS/MS, GC/MS/MS, FT-NIR, ion chromatography, CHNSO analysis, TOC and molecular biology analysis (PCR, DGGE and RT-PCR).

SERC represents the UK in several international R&D bodies. These include:

- The International Water Association (IWA) Specialist Group on Anaerobic Digestion (Western Europe Representative)
- IWA Anaerobic Digestion Task Group on the Harmonisation of Anaerobic Biodegradability / Activity / Inhibition Test Methods
- International Energy Agency Bio-Hydrogen Programme (IEA-HIA)
- International Partnership for the Hydrogen Economy (IPHE)
- International Centre for Hydrogen Energy Technology (ICHET)

The University of Glamorgan also provides structured training at masters' level since 2004 where AD technology features in an MSc course entitled 'Renewable Energy Resource Management'. Subjects such as waste management, wastewater treatment and bio-energy include significant reference to AD technology and biogas as an energy source. Currently, an average of 12 postgraduate students leaves the University every year with significant knowledge and expertise in related AD technologies. In addition, SERC has delivered many PhD programmes related to AD and biogas research and will continue to do so if R&D is supported, both at government and market levels.

In 2007, SERC with financial support provided from the Welsh Assembly Government and RCT-CBC, published the following report *Monson K D, Esteves S R, Guwy A J and Dinsdale R M (2007) Anaerobic Digestion of Biodegradable Municipal Wastes – A Review, University of Glamorgan ISBN 978-1-84054-156-5.* The first full scale plants treating kitchen wastes were commissioned in the late 1980's and are still successfully operating. As operator knowledge and experience have developed, confidence in the process has grown and more and more AD systems have been commissioned. These plants have proven their feasibility and important contribution across many countries in Europe and others across the World and many have been constructed in recent decades with exponential growth since 2000 and many more are still planned. This report includes a series of case studies reviewing 17 AD facilities treating biodegradable municipal wastes (BMW) around Europe. Some of these facilities co-digest BMW with animal wastes, commercial and industrial wastes, crops and sewage sludge. The case studies presented contain in-depth information on issues such as process configurations, the anaerobic digesters themselves, other components of the process chain (e.g. waste/biomass supply, biogas upgrading and utilisation, pre-treatments and post treatments required), content and quality of incoming wastes/biomass, suppliers/commissioners, ownership and location issues, populations served, energy and economic issues and lessons learned. These valuable lessons learnt from other European countries have been disseminated through this report and further best practices will continue to be brought to Wales and the UK via the Wales Centre of Excellence for Anaerobic Digestion. The AD Centre will continue to disseminate through events and website various case studies which scope extends from various digester systems treating municipal, C&I, sewage sludge, animal slurries and energy crops. The case studies will continue to include systems for upgrading biogas to biomethane for vehicle use and injection to the gas grid, as well as more conventional combine and heat and power (CHP) systems. The production, enhancement, utilisation, markets and benefits of digestate will continue to feature.

In 2004, SERC ran a two day Workshop on 'Anaerobic Digestion Solutions for the UK'. The presentations and discussions covered technologies for industrial wastewaters, organic wastes and sewage sludge treatment and energy recovery. The event also included policy and regulatory frameworks, economics and the commercial opportunity as well as the barriers for deployment. Although the event had over 80 delegates in attendance for each day, most of the audience were technology suppliers rather than stakeholders and end-users. This scenario has certainly changed and AD has finally gathered momentum in the UK, as shown by the interest shown at many events run throughout the country and by the AD plants that are currently being planned. Policy, regulation and fiscal developments have taken place recently, which make AD an attractive technology for implantation in the UK. In Wales, this has been evident in recent events that the AD Centre has organised for Welsh Local Authorities namely the 'Anaerobic Digestion Seminar' in September 2008 where 19 out of the 22 local authorities in Wales were present. This trend was also evident at the 'Implementing Anaerobic Digestion in Wales Workshop' in November 2008 where 120 delegates attended bringing together UK wide policy makers, local authorities, AD technology suppliers, AD merchant providers, stakeholders within the agricultural sector and waste and energy consultancy companies.

Policy, Regulation and Fiscal Developments

Recently, there have been major developments in terms of policy and regulation and financial frameworks that intend to support a faster and more effective implementation of AD in the UK i.e.

- attribution of 2 ROCs/MWh for renewable electricity generated using biogas
- development of the quality protocol (waiting European approval) and the PAS 110 for digestates (currently at draft stage) - an accredited digestate will then be consider a product and therefore able to exit the waste regulation framework – ultimately improving markets for digestates
- revised waste exemptions from environmental permitting (however implementation has been delayed)
- development of standard environmental permits related to AD facilities and storage of digestate, which will be shortly going out for consultation - this intends to accelerate the application process and will facilitate permitting for facilities within a certain waste throughput and maximum rated thermal input for biogas utilisation equipment
- initiation of a framework for renewable energy tariffs for electricity, heat and biomethane to the gas grid with full implementation expected by 2011.

Although the value of the financial incentive provided currently through 2 ROCs for the electricity generated from biogas is attractive, it is market dependant and subject to changes in the banding scheme and therefore it is still seen as a financial risk by many stakeholders developing AD projects. In order to have more bankable AD projects, there has been significant pressure from various renewable energy stakeholders in the UK to pursue a renewable tariff, providing a stable value for biogas over a longer period e.g. 20 years. After the Royal Assent in November 2008, the Energy Act 2008 enables the Government to introduce feed in tariffs for the generation of electricity in projects up to 5 MW and the Secretary of State to establish

a financial support mechanism for renewable heat including support for biomethane injected into the gas grid. Unfortunately, the Department of Energy and Climate Change (DECC) has indicated it will consult initially on the Renewable Heat Incentive in the summer of 2009, with the incentive introduced in 2011. The introduction of Feed-in Tariffs and Renewable Heat Incentive is very important for the fast development of AD projects and the diversification of uses for the biogas. It would be of benefit if the Government could make a statement from which a plant developed can qualify for tariffs and incentive as this would minimise the risk and would allow projects to proceed. The ROCs framework for AD is still running and will continue at least until 2037, however, a revision of the band for AD may take place in 2013.

UK Water Industry

It has been very encouraging that the UK Water Industry in a period of 3 years (2002/03 - 2005/06) has been able decrease the energy used to treat 1 Ml sewage from 814 kWh to 634 kWh and has increased the renewable energy generated from 343 GWh to 493 GWh, reducing their GHG emissions (Water UK, Towards Sustainability 2005/06). Anaerobic digestion has been considered the best environmental option for stabilisation of sewage sludge and UK Water companies treat currently approximately 66% of the sewage sludge produced using AD technology. Enhanced digestion systems for increased biogas production are attracting Water Companies' attention, and many are installing new AD plants and refurbishing older systems. Welsh Water/United Utilities is investing in new capacity for advanced digestion of sewage sludge and interested in optimising existing digestion assets. It would be of great benefit to assess opportunities of co-digestion of sewage sludge together with other organic wastes/biomass. There are various examples of this in Continental Europe. Also, implementation of other biogas utilisation technologies should be investigated by Water companies. Biomethane as a transport fuel and for injection into the gas grid is likely to have significant interest for Water companies in the very near future.

The following barriers have been identified against co-digestion of sewage sludge with other substrates: the ROCs issue (fiscal incentives in place provided has a lower band than for other substrates); ownership; capital cost; waste regulation and is seen as non-core business.

For example Severn Trent Water is now starting to build and plan digesters for energy crops.

Potential for Biogas Production

Biogas production from organic wastes can vary in different digestion systems with different loading regimes, different total solid content percentages, different mixing efficiencies, different operating temperatures and different retention times among other parameters. Methane percentage will also vary from waste to waste and system to system, and will determine the calorific (and therefore economic) value of the biogas. Extreme caution is required when previous knowledge is limited of the digestion capabilities of some wastes/biomass as inhibition can occur among or a

different operating regime may be required, as well when using statistical data for calculation of energy generation capabilities of a feedstock or a mixture. Specific anaerobic biodegradability tests should be carried out with the wastes to be treated in a system designed and operated as close as possible to that which will be used.

Biogas and Its Conventional Uses

Biogas contains normally 45-70% CH_4 and 30-45% CO_2 depending on the substrates and operation of digestion. There are also some minimal quantities of ammonia, hydrogen sulphide, oxygen, nitrogen, water and with some plants also siloxanes. A desulphurisation system is often required depending on the sulphur content of the substrate prior to the use of biogas. In most countries, including the UK, Government policy and market conditions have favoured the use of biogas to produce renewable electricity. In other countries, different Government priorities and different market conditions see the biogas being used more recently in other ways.

The common technology to use this energy source is currently the biogas combustion in CHP systems normally using gas engines generating an electrical efficiency of 35-40%. At the same time, heat is produced at approximate efficiencies of 40-50%. For larger plants with higher electrical generation rating, gas turbines can also be used with high efficiencies and a gas turbine allows a greater fraction of the waste heat to be recovered as more valuable steam. Unfortunately, in many plants apart from being used to supply heat to the digester and pasteurisation system, and for some space heating, the rest of the heat is wasted, which can be a substantial amount of energy.

Wales before defining locations for these plants should plan for the heat to be used in local industry, businesses, recreational centres and hotels, domestic homes or municipal facilities (schools, care homes, etc). The use of this heat is of vital importance for an ecologically efficient operation and also economically and therefore, WAG should act to encourage the development of district heating networks. A report by Pöyry and Faber Maunsel, commissioned recently by DECC noted that district heating provides less than 2% of UK heat demand compared to 18% in Austria, 49% in Finland and 60% in Denmark. Cost being the main barrier to expansion.

Biogas upgrading can be an alternative solution to the production of distributed electrical energy and heat, especially if heat use is not viable locally. Processed biogas could be used as a natural gas substitute in households, or industry or as a fuel for transportation purposes.

Fiscal Incentives for Renewable Electricity in Other European Countries

A report by the EU Biogas Regions Project provided an overview on remuneration for energy produced from biogas in 9 EU countries (Austria, Belgium, England and Wales, France, Germany, Italy, Poland, Slovenia and Spain) as regulated for the year 2008. The support varies in theses countries but is largely based on feed-in tariffs for renewable electricity.

For example, feed-in tariffs for renewable electricity exist in Germany since 2000 and reviews have taken place. The period of payment is guaranteed for 20 years, but reduced by 1.5% / year but it can change in the case of new or additional construction. The tariff depends on size (kW_e) and age of the plant, feedstock, technology (innovations in machinery/technique and/or so called 'dry' fermentation), CHP (efficient utilization of produced heat). There are bonuses for purely agricultural substrates, bonus for CHP with heat use and bonus for new technologies. See tariff scheme below for 2008.

Tariff in €ct/kWh	**up - 150 kW_e**	**151 - 500 kW_e**	**501 kW - 5 MW_e**	**5 - 20 MW_e**
basic prices (year of start-up = 2008)	10.83	9.32	8.38	7.91
bonus for purely agricultural substrates	+6	+6	+4	0
bonus for CHP – use of heat	+2	+2	+2	+2
bonus for new technologies	+2	+2	+2	0

Source: EU Biogas Regions Project (2009)

Germany is introducing a policy for biomethane for injection into the gas grid that does not follow the tariff system.

In Austria feed-in tariffs for green electricity have existed since 2002. The remuneration is calculated based on the amount of green electricity that is fed into the grid. A minimum overall efficiency of 60% for electricity and heat production is required. The tariffs are guaranteed for 15 years. A use of non-agricultural substrates reduces the tariff by 30%. The tariffs depend on the generation size of the plant and range between 16.94 ct/kWh (100 kW_e only agricultural substrates) to 7.9 ct/kWh (>1000 kW_e mixed substrates). In 2008, an additional bonus of 4 ct/kWh due the high prices for agricultural substrates was granted.

Biogas Upgrading

Various technologies for upgrading biogas to biomethane (i.e. removal of gases such as H_2S and ammonia, drying, and separation of carbon dioxide, nitrogen and oxygen) are currently being used at full-scale. Upgrading technologies are continuously being developed and improved. There are different size plants and operating experience has improved. There are currently in the market reliable and low energy consumption technologies. Costs and fugitive methane emissions have been reduced. Processes within the upgrading chain that separates carbon dioxide are typically pressure-swing adsorption, temperature-swing adsorption, water scrubbing (with thermal regeneration), amine scrubbing and cryogenic separation. A simple and compact membrane separation process has recently been installed and tested in two plants in Austria with positive results.

Biogas and Fuel Cells

The Bioenergy Plan states that Wales should keep abreast of developments involving fuel cells linked with AD units and consider potential applications in Wales. Fuel cells have good potential for providing electricity and heat using biogas directly or after conversion to hydrogen. Fuel cells are power generating systems that produce DC electricity by combining fuel and oxygen (from the air) in an electrochemical reaction. There is no intermediate process which first converts fuel into mechanical energy and heat. Fuel cells have extremely low emissions and high electrical efficiencies are expected. Further developments are and will continue to take place.

Biomethane as a Transport Fuel

For example 1 tonne of BMW can power a car for approximately 1000 km. Based on the National Society for Clean Air (2006) calculations, the total biogas potential from AD in the UK is around 7.4 billion m^3 of biomethane (of which 2.5 billion m^3 is from domestic food waste, and 2.1 billion m^3 from commercial food waste).

Although the concept of biomethane being used as a vehicle fuel has only over a decade, it can be used in natural gas vehicles and according to the European Association of Natural Gas Vehicles, there are more than 7 million natural gas vehicles in use worldwide and its use will continue to increase. Natural gas cars allow a driving distance of 200-400 km. These cars can also be equipped with a petrol tank that gives an additional driving distance.

The following statistics are as of 2006. Spain had more than 500 public sector natural gas vehicles operating in Madrid, including buses and refuse collection vehicles. With over 7000 vehicles and 67 biogas refuelling stations, Sweden is the most advanced country in Europe with regards to developing the potential of biogas as a transport fuel. Biomethane as a transport fuel is also well established in Switzerland. In Zurich alone, five plants ferment organic wastes from homes and restaurants to produce fuel for 1200 cars and trucks. In Europe, there were at least 12 models of cars, from 8 different manufacturers, commercially available that used gas or a combination of gas and gasoline or gas and diesel. There were also a wide range of van, trucks and also some buses.

Today, the use of biomethane as a transport fuel is proven and developed, with further implementation more a question of policy, marketing and industrialisation. In the UK there is currently no standard for biomethane as a vehicle fuel. Sweden has had one for some time. To use biogas from anaerobic digesters as a transport fuel the biogas must first be upgraded, to approximately 97% methane, compressed and stored to around 200 – 250 bar either for distribution or directly into the vehicle gas storage. Upgrading of biogas to transport fuel quality is common practice in several countries (including Sweden, Germany, the Czech Republic, France, the USA and New Zealand).

As compared to fossil fuels, biomethane is a low carbon fuel, provide air quality benefits, vehicle noise reduction and safety can even be increased due to higher ignition temperature than other fuels.

The advantages of biomethane as a transport fuel as compared with other renewable transport options are that its production can be localised anywhere (reducing further transport of fuel) urban or rural, it is not dependant on markets in some cases foreign markets, it is not dependant on large mono-crop production as it can be produced from a wide range of energy crops. Biogas has a higher yield (in terms of km/hectare than any other bio-fuel. Biogas can also and mostly importantly be produced from wastes, therefore providing additional benefits. A range of biofuels produced from crops grown in the UK have been compared by researchers in SERC in terms of their energy balance, waste/co-products, and exhaust emissions (*Patterson T., Dinsdale R., and Esteves S. (2008) Review of energy balances and emissions associated with biomass-based transport fuels relevant to the United Kingdom context. Energy & Fuels 22 (5), 3506-3512*). Crops assessed for biomethane production were rye grass, sugar beet (whole crop) and forage maize. Biomethane from the AD of crops was found to have a more favourable energy balance for the production of transport fuel than biodiesel or bioethanol (237 011 MJ/ha compared to 24 185 and 77 264 MJ/ha, respectively). Tailpipe emissions were superior for biomethane, with lower emission levels of CO, CO_2 and particulates and lower NO_x levels than biodiesel, which are comparable to bioethanol. Where land is to be used to produce energy for transport fuels rather than food, there is at least the obligation to use this land in as efficient a way as possible by using the technology that yields the most energy.

In the UK, for example the compressed natural gas (CNG) duty is currently 19.26p/kg and from 1st September 2009 it will be 22.16 p/kg and this applies to biomethane. Biomethane is eligible for Renewable Transport Fuel Certificates (1 kg of biomethane earns 1 certificate). The Renewable Energy Directive (RED) is likely to be published soon with a deadline for implementation of November 2010. The implementation of the RED may have a number of implications for the 2010 RO order. Under the RED, biofuel generated from waste may get further incentives as compared to food crops.

Other countries have successfully incentivised the utilisation of biomethane as transport fuel. For example, in Germany the government agreed to fix fuel duty on CNG at the EU minimum level of 6 p/kg until 2020, while the gas companies agreed to build a national network of CNG filling stations and the car manufacturers agreed to produce CNG cars. Sweden leads the world in terms of the use of biogas as a transport fuel. This is mainly a result of the Swedish Government's active promotion of AD and biogas transport initiatives through R&D and fiscal taxation policies. These policies are a direct result of the Swedish Government's plans to be independent from oil by 2020. This ambitious forward thinking target prioritises renewable energy development in all three energy sectors electricity, heating and transport. Sweden has a standard for upgraded biogas (SS 15 54 38: 'Motor fuels – Biogas as a fuel for high speed Otto engines'). The first biogas/natural gas filling station was in Malmo in 1997. The Swedish Government promoted the use of biomethane vehicles for taxis, company car fleets and private citizens. In Sweden, there is no duty for biomethane in addition to a series of other incentives such as free parking; lower tax on biomethane vehicles when used in commercial traffic; exemption from city gate tolls for biomethane vehicles; special lanes for biomethane taxis; financial support for investment in biomethane vehicles. These incentives have proved successful despite the higher cost of vehicles.

Another possibility is liquid bio-methane as a vehicle fuel. Recently the first UK commercial operated vehicle running on liquid biomethane from a new facility at the Albury landfill in Surrey has been trialed for collection of refuse. It can fuel up to 110 heavy good vehicles and cover up to 110,000 miles per year. A UK supermarket is also delivering food products using a dual fuel vehicle running on diesel (or biodiesel) and biomethane. The consortium delivering this project has claimed a reduction of up to 60 tonnes of CO_2 per year, compared to its diesel counterpart. The biomethane conversion technology can be used at an AD plant where a higher quality biogas is produced and which will be receiving in the future the biodegradable wastes that would be going to landfill.

Local authorities and food and drink industry that will deploy AD for treating their wastes should assess the business case for producing biomethane for transport fuel for use in vehicle fleets.

Biomethane Injection Into the Gas Grid

Injection of upgraded biogas into natural gas pipelines is a relatively new practice and a variety of criteria are used in different member countries before injection may take place. Countries such as Germany, Austria, the Netherlands and Switzerland allow injection of biomethane into the gas grid.

Natural gas is a very popular fuel in Europe and the industry, power generation and households depend largely on this source of energy. Following an expensive pipeline infrastructure implementation in many countries including the UK, its use is associated with advantages such as low transportation costs by pipelines and low carbon dioxide emissions as compared with other fossil fuels. There has been a recent impetus in the UK for injecting biomethane into the gas grid. This has been promoted by the fact that as stated in the Energy Act 2008, the UK will rely on imported gas to meet up to 80% demand by 2020 as well as the recent gas supply row Russia-Ukraine. The replacement of natural gas with upgraded biogas is a scenario that has recently been very welcomed by the National Grid and which the Gas Distribution Networks also favour. Ofgem's approval is required before the later will make adjustments changes such as to the gas regulators to allow higher pressures in the lower gas demand period. Also changes to the regulation to allow a higher percentage of oxygen gas to be injected without compromising safety and a commercial incentive for renewable gas to be upgrade and injected into the grid are required.

The possibility of injection of biomethane to the gas distribution network(s) to replace natural gas can offer significant advantages for the UK:

- Increase security of gas supply reducing external dependence – North Sea natural gas supplies decline;
- Possibility for decarbonisation of the UK gas network – help fulfill European policy
- Flexibility for its use i.e. direct combustion for heating, transport fuel or electricity generation – resulting in an improved energy supply and demand response
- Offering possibility for country-wide transport fuelling stations
- Improved energy conversion promoting reduction of carbon emissions

    - direct burning for direct heating - in high efficient boilers using existing infrastructure/appliances
    - use for electricity generation in combined cycle gas turbine systems with a higher electrical efficiency than CHP units using reciprocating gas engines. Especially if in the latter, a significant amount of heat does not find a local use and is to be wasted.
        - when generation of electricity in the UK by 2020 is expected to be provided by a significant amount of wind energy with the shortfall largely generated from natural gas. Then biomethane may be used to replace imported natural gas; it is easier to store gas than electricity
- Support local economy

Before biomethane can be injected into the gas grid the biogas must be upgraded, in addition, it requires appropriate compression depending on the pressure of the gas network injecting to and requires also odorisation for safety reasons. In addition, around 4% propane may need to be blended to match the calorific value of the UK grid gas. The biomethane will need to be monitored in terms of flow and quality. The lower the pressure network used for injection the least compression effort is required and normally closer injection connections which will mean less cost. However, spare capacity for injection may be limited in lower pressure networks and gas may be to be pumped to higher pressure networks.

R&D Related to the AD and Biogas Sectors

It is important that new R&D activities as well as past suggested improvements are disseminated so that the developments can be taken on board by the industry.

State of the art biogas plants can operate with reasonable efficiencies for the digestion process and production of biogas and digestate and steps are generally employed towards minimisation of impacts such as emissions and odours. It has been established when interacting with AD suppliers and operators that there is still significant room for improvement in the conversion efficiencies of various feedstocks in many full-scale plants around Europe and in the use of the various products resultant from the AD process as well as in their environmental performance.

Governments, owners/operators, planners and neighbours have different expectations from these processes that can be summarised in a very effective delivery operationally and environmentally as well as in financial terms. Improvements in the design and operation of AD and biogas utilisation facilities, in the quality of end products as well as in the integration of all processes part of the supply chain will ensure that the chain within the UK is not just fit for purpose, but where possible use state of the art systems which are operated effectively to provide the maximum economic and environmental performance. This will benefit the whole community by effectively treating wastes, producing energy and a valuable fertiliser as well significantly reducing GHGs along the life cycle.

Therefore, the UK Governments should support a comprehensive R&D programme for the enhancement in efficiency of AD and biogas utilisation technologies as well

has the demonstration of their benefits. In the UK, there has been a lack of funding available to support applied research activities related to these technologies. Research centres with suitable track-record are best placed to conduct pure and applied research as well as to support demonstration projects and activities. R&D should in many cases be developed closely with industry in which case sponsorship may be expected from the industry.

The Sustainable Environment Research Centre (SERC) has and continues to carry out fundamental and applied R&D that contributes to developments in the industry. The Wales Centre of Excellence for Anaerobic Digestion proposes the following R&D themes:

- Evaluate and improve waste collection methods
- Develop innovative packaging that is fit for purpose but is also anaerobically digestible
- Assess available pre-treatment processes and develop others for superior hydrolysis that will allow efficient digestion of non-food ligno-cellulosic biomass and biodegradable packaging
- Assess the potential for local growth of biomass with low water and fertiliser demands as well as water-born biomass as feedstocks for AD
- Improve crop ability to yield more biogas
- Integrate AD with other complementary energy producing processes e.g. bio-hydrogen fermentation, microbial fuel cells for maximum energy recovery
- Evaluate and optimise the integration of AD with other processes such as algae and intensified food production for enhanced carbon abatement – use of CO_2 and digestate
- Integration of AD with biogasification process e.g. thermal treatment of low quality digestates and gas clean-up
- Development of novel recovery methods for intermediate digestion products as well as for the digestate for the production of high value products
- Develop novel AD process monitoring and modelling tools
- Optimise feedstock and digester management
- Evaluate and improve gas upgrading and biomethane utilising technologies e.g. fuel cells
- Improve processing of digestate and its utilisation
- Define digestate quality as a soil fertiliser and conditioner and a growth enhancer for aquatic biomass
- Evaluate and reduce emissions and visual impacts from biogas plants
- Analyse the environmental footprint of various technologies within the biogas supply chain and their operation
- Evaluate the potential for cost reduction
- Model energy supply and demand scenarios for heat, electricity and transport fuel generated from biomethane injected to the gas grid - maximise energy efficiency, and minimise climate change impact integrating with future sources of renewable energy generation e.g. electricity from wind
- Evaluate long-term effects of biomethane in pipelines and combustion appliance

Summary of Further Actions

There are still urgent actions by policy makers and regulators required for an effective implementation of the AD industry in Wales (and in the UK). The Wales Centre of Excellence for AD has drawn here some suggestions for which action is required not only by WAG but also at a UK level.

1. Along with more conventional CHP solutions, biomethane used for transport fuel and for injection into the gas grid should also be considered in Wales which should not continue to ignore gaseous transport biofuels:
   - These latter two options may be very attractive in locations where connection to the electricity grid is not possible or has high costs or for medium and large biogas plants in Wales able to generate electricity but where locally generated heat is unable to find a market
   - Operational, environmental and financial benefits in each case should be assessed
   - Development/acceptance of an (existing) biomethane to the gas grid standard and implementation of a regulatory framework

2. In addition to the financial support provided to biomethane as a transport fuel under the RTFO or in the future with the implementation of RED, revision for a lower fuel duty, support should also be provided to the general users of biomethane run vehicles e.g. for refilling stations infrastructure development and vehicle premiums
   - Initiatives to incentivise the purchase of vehicles that run on biomethane could be a way of promoting national manufacturing, trade and decreasing the effects of the financial crisis within the automotive sector. It would also contribute to significant environmental benefits.

3. Early definition of levels and implementation for renewable energy tariffs. The introduction of Feed-in Tariffs and Renewable Heat Incentive is very important for the fast development of AD projects and the diversification of uses for the biogas.

4. Improved integration of waste management and rural policies
   - For co-digestion when beneficial
   - For effective use of digestates
   - For effective utilisation of CO_2 in food growth production

5. The implementation of AD to minimise the carbon footprint of the agriculture sector should also be seen as a priority. Capital support (or enhanced RET) for plants treating agriculture residues, if reduction of GHGs are to take place effectively in the UK farming sector

6. Careful assessment of the potential for local growth of biomass with low water and fertiliser demands as well as water-born biomass as feedstocks for AD and assess if enhanced support via capital or RET for the digestion meets environmental targets without compromising food supply would be required

7. Additional financial support for innovative plants that demonstrate enhanced environmental performance
   - For example advanced monitoring and control schemes should be a pre-requisite for installations dealing with municipal, and most commercial and industrial wastes and essential analytical equipment should be a requirement

8. Implementation of a procedure by Ofgem for claiming ROCs when various feedstocks e.g. food wastes and sewage sludge are co-digested in the same facility and also for the cases where CHP units are shared between landfill sites and AD schemes

9. Liaison with Ofwat in order for Water Companies to engage in the provision of other services that go beyond their core activity of providing treatment for water and sewage

10. Continue the support to the Wales Centre of Excellence for AD

11. Invest in R&D for improved performance and environmental benefits for the AD supply chain

12. Support training of stakeholders which influence AD implementation

The Wales Centre of Excellence for Anaerobic Digestion
Sustainable Environment Research Centre
University of Glamorgan
Pontypridd
CF37 1DL
http://www.walesadcentre.org.uk

22nd May 2009