Environment and Sustainability Committee

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Inquiry into energy policy and planning in Wales - Evidence from Dr Sandra Esteves, Wales Centre of Excellence for Anaerobic Digestion, University of Glamorgan

Written Evidence To Be Considered As Part of the Inquiry Into Energy Policy and Planning in Wales

Anaerobic Digestion in Wales

Written by

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1.0 BRIEF INTRODUCTION TO THE WALES CENTRE OF EXCELLENCE FOR ANAEROBIC DIGESTION

The Wales Centre of Excellence for Anaerobic Digestion based at the Sustainable Environment Research Centre at the University of Glamorgan was established in 2008, largely as a response to the recognition of anaerobic digestion (AD) as the preferred technology for treating and recycling municipal source segregated food waste, and that expert technical input was required to assist with the development of an appropriate waste treatment infrastructure. The Centre's overall aim is to facilitate the development of a robust AD infrastructure in Wales, to foster innovative solutions that maximise the environmental and economic benefits of the process and products, and to encourage long term growth of the AD and biogas industry. To do this the Centre acts as a process development and deployment support platform and delivers industrial focused R&D, feedstock and digestate analysis, system design, monitoring and diagnostics, support for policy and regulation definition, provision of general support and guidance for a number of stakeholders and awareness raising, training and knowledge transfer among other activities. The centre also provides direct support and funding for innovation within the AD and biogas sectors. The AD Centre has been funded by the Welsh (Assembly) Government (WG), the European Regional Development Fund (ERDF) and the University of Glamorgan.

The Centre currently employs:

- Centre's director (70% Full time Equivalent),
- Business and Information Manager (100% Full Time Equivalent),
- Laboratory officer (100% Full Time Equivalent)
- Technical adviser (100% Full Time Equivalent)
- Administration officer (60% Full Time Equivalent)

The two funding streams have allowed the delivery of complementary activities with a special emphasis on support provided on a whole Wales basis for local authorities, policy makers, regulators and enterprises from the WG funding stream. ERDF funding has allowed the delivery of support to Convergence based enterprises and the generation of jobs, as well as the provision of grants for eligible SMEs for the development of new or improved processes, products or services related to the AD and biogas sectors.

The Centre has provided support to the Welsh Government, Local Authorities and other stakeholders with the implementation of the ongoing waste infrastructure procurement programme. Strategic work undertaken by the Centre also includes the initial assessment of anaerobic biodegradability of a variety of bioplastics (relevant to food waste collection liners) and an investigation of the characteristics of a range of digestates and their influence on dewatering (relevant for final disposal, utilisation and recycling of digestates).

One of the Centre's core activities under both the WG and ERDF programme is the dissemination of technical and non technical information. The Centre's intention on this front has been to always provide technically accurate and technology independent information to all stakeholders, and this continues to be the case. As such the Centre has organised and delivered a range of dissemination events (Appendix A) and presented at a large number of events organised by third parties (only recent examples are listed in Appendix B).

The Centre has developed a comprehensive website (www.walesadcentre.org.uk), which provides a wide range of information relating to the AD industry in Wales and the UK. This includes case studies from AD plants across Europe as well as a summary of the technical and legislative frameworks within which the AD industry must operate. The development and launch of our Suppliers Database in late 2010 was a significant achievement and the database has surpassed our expectations. We currently have the profiles for over 240 companies involved in the AD and biogas supply chain on line and their information is available for all registered users to search. The website currently receives around 500 individual users each month, primarily from the UK, but also from continental Europe, the USA, Canada, India and China. 65 No. enquiries have been received via our 'Ask the Experts' facility and all enquiries have received a reply. Many others reach us on daily basis directly by phone or email.

The Wales Centre of Excellence for Anaerobic Digestion has had direct interaction (i.e. met and discussed) with over 100 companies and organisations located within Wales and across the UK. Our activities are not geographically limited to the borders of Wales as many organisations outside of Wales have either expressed an interest in working with companies within Wales, or are undertaking operations with direct relevance to the AD industry in Wales.

It is this day to day interaction with industry and stakeholders, that has allowed the Centre to meet the targets set under the ERDF programme of 'Companies Assisted' (36 achieved so far) and 'Gross Jobs Created' (3 achieved so far) within eligible, Convergence Region organisations.

The Centre also provides targeted financial support to allow eligible Convergence Region SMEs to develop or implement new or improved products, process or services. Through this route, the Centre is working with a number of Welsh companies who are developing innovative solutions to some of the technical problems still faced by the AD industry. These include development of improved small scale CHP plants and the automated monitoring and optimisation of AD processes.

The Centre has also embarked upon a programme of internal technical development across a number of areas relevant to the AD industry. Results are disseminated directly back to relevant stakeholders and in most cases made available to all on a non-discriminatory basis. Examples of targeted developments are as follows:

1. Establishment of Standard Methodologies for Characterising Feedstocks and Digestates

2. Development of Analytical Methods:

    - the determination of the biogas / methane generation potential for feedstocks and digestates
    - the measurement of volatile fatty acid concentrations in a sample (work is continuing for on-line analysis)
    - microbial assays for profiling digester populations (work is continuing)
    - monitoring siloxanes (initial development)
    - comparison of dewatering efficiencies (initial development)

3. Digestate Dewatering and Nutrient Recovery Processes:

    - Monitoring of samples generated from the mechanical dewatering of digestates including the use of polymers to flocculate fine particles.
    - Determination of the relationship between particle size distribution and COD and how dewatering technologies can impact on these parameters.
    - A wider characterisation of a variety of digestates source from full-scale plants has also taken place
    - Zeta potential monitoring and particle size distributions
    - Laboratory based jar testing of polymers
    - Laboratory based belt press simulation

4. Study of Reactor Microbial Populations
5. Addition of Supplements to the AD Process
6. Pre-Treatment Technologies for Feedstocks
7. Economic and Life Cycle Assessments

All outputs are directly applicable and beneficial to the AD industry in Wales and the UK, and many outputs have also been published in academic papers as listed in Appendix C.

2.0 SUMMARY OF POINTS TO MAKE WITH THE COMMITTEE

2.1 Environmental and Economic Benefits of Anaerobic Digestion

Anaerobic Digestion is a unique technology that delivers integrated services to society. It can deliver environmental benefits and economic opportunities through a number of means, namely;

1. Diversion of solid and liquid municipal, commercial and industrial waste material from landfill or other treatment options with higher emissions, therefore reducing overall CO_2 equivalent emissions;
2. Stabilisation of agricultural wastes (e.g. slurries), reducing GHG emissions and nuisance issues such as odour;
3. Ability of co-digest a number of feedstocks that can allow plants to become feasible at a local level;
4. Biogas produced from the process can be utilised to produce renewable heating or cooling and electricity, or upgraded to biomethane for grid injection and / or vehicle fuel use. After upgrading, methane and carbon dioxide can also be used as chemicals. This displaces fossil fuels and therefore delivers additional GHG savings;
5. The process allows the recovery of nutrients (N, P, K, S and other trace elements) present in the feedstocks, which can then be applied for plant and algae growth, essentially displacing the use of fossil fuel produced fertiliser;
6. Development of green skills and jobs – research and education, consultancy, manufacturing, agriculture, construction, waste treatment, gas and electricity supply and distribution sectors.

The growth in AD is fuelled by several European Directives, applicable across all member states, which are acting to divert organic material away from landfill sites, require that all biodegradable wastes are pre-treated prior to disposal, decrease CO_2 emissions and increase the amount of renewable energy that is produced. Anaerobic digestion is a distinctive technology in that it can contribute towards all of these targets. In recognition of this, many countries are producing strategies for rapidly deploying AD technology within a waste management and / or agricultural setting e.g. in the UK DEFRA has published the Anaerobic Digestion Strategy and Action Plan for England. In Wales, anaerobic digestion has been identified by the Welsh Government (WG) as the favoured option for the treatment of municipal food wastes (Figure 1). WG has made funding available to local authorities wishing to develop AD plants to treat source segregated food wastes.

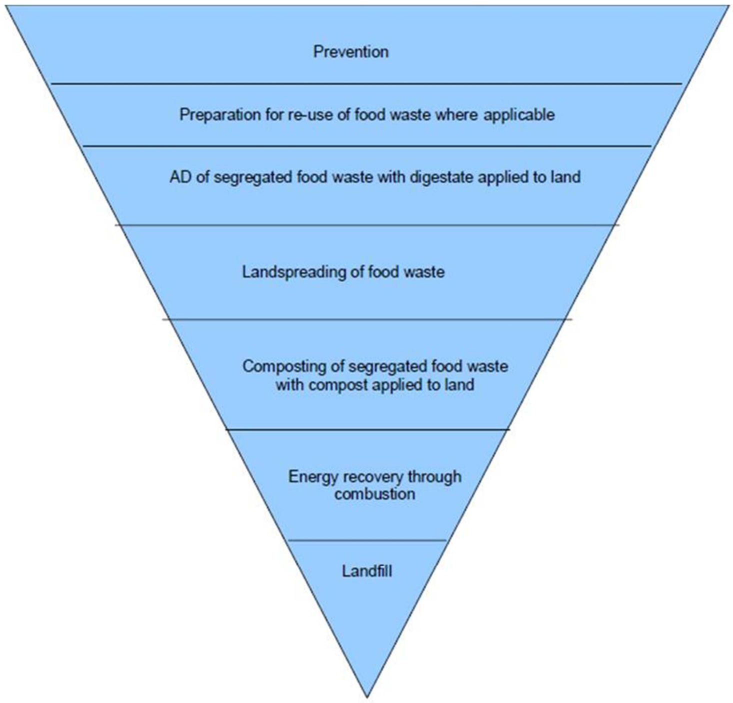

Figure 1 – Proposed Waste Hierarchy for Food Waste in Wales[1]

Across Europe, there are more than 10,000 biogas plants in operation predominantly treating organic wastes and energy crops. The scale of the biogas industry across Europe increased rapidly between 2001 – 2009, as indicated in Table 1.

Table 1 – Biogas Production in Some European Countries (2011-2009)

Country	**Biogas Production (inc. Landfill Gas) (Kt of oil equivalent)**							
	2001†	**2002†**	**2003†**	**2004†**	**2005†**	**2006†**	**2008***	**2009***
Germany	600	659	685	1291	1594	1923	4229.5	4213.4
UK	904	1076	1151	1473	1600	1696	1625.4	1723.9
Italy	153	155	155	203	344	354	410	444.3
Spain	134	168	257	275	317	334	203.2	183.7
Austria	56	59	64	42	31	118	174.5	165.1
Poland	57	63	72	43	51	94	96.1	98

Source: †EurObserv'ER, Biogas Barometer 2001-2006[2]
* EurObserv'ER, Biogas Barmoeter 2008-2009[3]

This expansion is expected to continue, particularly as countries face a reduction in the amount of landfill gas that can be recovered and seek to develop a stronger AD sector by utilising organic wastes and in some countries also energy crops. This pattern has already been seen in countries such as Germany and Austria, and is currently being adopted in many other countries across Europe.

As an example, the biogas industry in Germany in 2006 was estimated to employ around 10,000 people and was worth over €1 billion 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 uses is likely to take place.

Even countries with a relatively mature biogas industry (e.g. Germany, whose biogas companies now generate annual sales of around 2.3 billion Euros (German Biogas Association, 2011))[4] are predicting sustained growth over the coming years.

The AD Centre is a partner within the EU-IEE Biomethane Regions project and the intended growth of the sector is clearly indicated by activities and feedback from project partners (both industry and energy agencies) within eleven countries in Europe. Therefore, the growth in emerging countries is anticipated to be fairly rapid as well.

This means that the AD industry is expected to see continued strong growth across Europe. In a recent market report[5], BCC Research quantified the market for AD and landfill gas equipment in Europe at 2.4 billion dollars in 2011 and that this would increase to 5 billion dollars by 2015 (an annual growth rate of 15.8%). It is worth reemphasise that this is only related to equipment. 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.

In the UK, at least 71 AD plants have been implemented for the treatment of municipal, commercial and industrial wastes over the past 3 years, indicating that the UK market is presently moving into its growth phase. A similar situation is occurring in France and Belgium, and very rapid growth is expected in Eastern Europe over the coming five years.

A key point to note is that the environmental and economic benefits of the AD process are maximised when the process is integrated either with processes that generate feedstocks (e.g. food production, other waste management sites), or where process outputs (heat, electricity, biomethane, digestates) can be efficiently utilised. The use of this heat is of vital importance for an ecologically efficient operation and also economically unless biogas is cleaned up and upgraded, WG should act to encourage the development of heat utilisation schemes for domestic, commercial or industrial uses. 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.

High public acceptance, being a good neighbour as well as achieving good environmental and economic performances from plants, benefits the progress for further deployment of the technology. It will be of benefit for businesses, government and Wales as a whole that plants with life times of 20 years and more, will be built in appropriate locations, featuring best practice and efficient designs. In addition, these plants should operate aiming at an appropriate management of feedstocks and maximising stabilisation of feedstocks and biogas production. At the same time these plants should be capturing most methane and ammonia emissions, removing hydrogen sulphide from the biogas for H&S reasons as well as improving digestate and biogas use.

Environmental performance should be a key factor at selection of the site and at design stage and the plant should be monitored throughout its operation. Already environmental permitting in the UK is ensuring that environmental impact is reduced and plants operate at a reasonable performance; even greater environmental benefits from these plants can be sought and those could be reflected in the incentives regime in the future. Other countries such as Germany are already providing bonuses related for example with biogas upgrading systems, where methane fugitive emissions are below 0.5% of the raw gas. Appropriate plant design, operation and maintenance can reduce fugitive emission of methane and ammonia. A high quality digestate and how it is handled and used is also important not just in terms of providing maximum benefits as a fertiliser and soil conditioner, but also in minimising volatile emissions, odours and plant phytotoxicity.

Overall quantitative environmental assessments of AD plants can only be performed if:

1. Feedstocks utilised can be defined including their generation, collection and transport regimes to the plant;
2. What is the AD plant replacing e.g. landfilling, composting, incinerating or land spreading in case of treatment/disposal of wastes;
3. Full design of the plant as well as the operation regimes are known;
4. The full emissions from the plant are quantified;
5. Digestate quality and utilisation is defined - degree of stability, how are digestates/nutrients utilised (e.g. for the benefit of agriculture or others) and how much of fossil fuel fertilisers can be replaced; how would these have been produced and where would they have been transported from;
6. Use of biogas is defined e.g. so that the energy mix in the country/region is taken into consideration; vehicle fuel is defined as well as type of vehicle and duty cycles.

The boundary for a detailed environmental assessment is extremely wide and complex. Assessments should also be performed for a number of impact categories and not only for

GHG emissions. See section below where some data is presented that reflects the environmental benefits that can be gained from employing the technology.

AD technology, particularly for the treatment of municipal, industrial and commercial wastes, is still rapidly evolving, even in countries that are more advanced than the UK in terms of practical deployment. R&D is ongoing into all aspects of how the process, from feedstock characterisation to final digestate utilisation, can be optimised to maximise the environmental and economic benefits and reduce impacts as far as is practicable. Key areas of research across Europe include:

1. Process monitoring and control to optimise treatment efficiency
2. Effectiveness of pre-treatment technologies
3. Benefits / limitations of trace element additions
4. Dewatering of digestates
5. Novel products from digestates
6. Measurement and reduction of fugitive methane emissions
7. Process integration with other renewable energy / sustainable technologies
8. Biogas upgrading technologies
9. Optimum approaches for utilisation of biogas and biomethane (e.g. novel burners, improved biogas/biomethane engines and solid oxide fuel cells)
10. Novel plant configurations and recovery of high value/ low carbon outputs (e.g. bioplastics, chemicals and nutrients)

The research community is continually widening and strengthening with the increased implementation of AD systems at full scale across Europe. A number of congresses, workshops and conferences have taken place and the events have been very well attended. For example, at the ADSW&EC in Vienna almost 300 attendees were present and 90 oral and 77 poster presentations took place and many more had attended the 12th World Congress on Anaerobic Digestion in Mexico in 2010. However, it is noticeable that recently, more short-term research programmes are taking place (some funded by industry), which sometimes tend to lack in academic rigor largely due to the non controlled conditions and short-term nature of the studies and do not lead to more conclusive results. It is important that R&D programmes are structured in a way that allows for valuable conclusions and relevant advancements in knowledge to be made. This is likely to only occur if both government and industry work together to support necessary R&D initiatives.

2.2 Current Status of AD in the UK and in Wales

In the UK, 2011 represented the year in which AD started to became firmly established as a waste management and renewable energy generation technology, with a number of industrial scale and farm based plants being commissioned treating a variety of feedstocks including municipal, commercial, industrial and agro wastes and energy crops. Of the 71 AD plants in operation in the UK (excluding the ones for sewage sludge treatment), 26 treat farm wastes and two of these are based in Wales; the other 45 treat in its majority organic wastes and one of these is based in Wales. In addition, a number of other plants are currently being planned and constructed.

A number of conferences, workshops and trade shows have taken place in the UK in the last couple of years and to highlight the stakeholder interest in this technology is the attendance of significant numbers at many of these events e.g. 200 exhibitors and 3000 visitors attended the July 2011 ADBA Conference and Tradeshow. The visitors spanned from government, academia, agriculture, waste and energy consultancy sector, equipment manufacturers, to the legal and financial sectors.

However, as per the number of plants on the ground, developments have been somewhat slower than anticipated. The aspects summarised below can be stated to be the main contributing factors for the slow implementation of the technology:

- Uncertainty over how economic incentives would be implemented such as the review of Renewable Obligation Certificates and changes in grandfathering, the delays and conditions related to the Feed In Tariff (FIT) and the Renewable Heat Incentive (RHI), have led to difficulties in securing or committing investment;
- Navigating the town and country planning system continues to be a formidable task, particularly to those who may not have previous experience of developing these type of plants or have experience but only in other countries;
- The long period for the issuing of the ADQP and the PAS 110 and now some uncertainties over the ‘end of waste criteria’ definition for digestate have also slowed down project implementation decisions;
- Quantifying and securing feedstock continues to be a significant hurdle for all AD plants, and in Wales in particular there is strong competition for what is, or will be, a finite amount of organic waste;
- Whilst the local authority based waste infrastructure procurement programme will undoubtedly deliver long term municipal benefits, it has probably contributed to the uncertainty over feedstock availability for merchant providers wishing to develop plants outside of the local authorities related procurement programme;
- The lack of reasonable length waste contracts has also provoked a delay in borrowing approvals;

- The poor economic climate has exacerbated the difficulties in financial borrowing especially when risks are still perceived due to the reasons above.

Despite these difficulties, the picture in Wales is far from bleak. Developers and stakeholders have been busy laying the groundwork required before physically constructing plants – this groundwork in itself requires large inputs of time, resources and finance and demonstrates the commitment shown by industrial stakeholders. This, coupled with some resolution of uncertainties mean that a more rapid development and deployment over the next few years is very probable.

It is clear that the AD and biogas industry in both Wales and the UK is entering a key phase. We are seeing a marked increase in the deployment of AD plants across the UK, and for Wales in particular, the period of 2012 – 2015 will be of particular significance including:

- The conclusion of the municipal food waste element of the waste procurement programme,
- The development of several merchant facilities across Wales,
- The onset of widespread utilisation of digestate materials,
- The requirement to demonstrate the effectiveness of the waste treatment infrastructure,
- The market exploration and development of options such as biogas upgrading, grid injection, digestate processing and nutrient recovery.

Continued support is therefore required to the industry, regulators and stakeholders throughout this important phase. Afterwards, further improvements of the process and integration with more novel approaches and equipment will be key for continually enhancing the environmental and economic status and benefits of these systems.

2.3 Current Barriers to Deployment of AD and Biomethane Projects in Wales and in the UK

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 the Water companies.

Another significant barrier for AD technology deployment in Wales is the ability to connect to the electricity grid. An increased capacity and strengthening of the electricity grid across Wales is still required. This will not only support AD operations, but also other biomass energy installations as well as wind and hydro electricity generation projects. It is also imperative that the Distribution Network Operators are set reasonable deadlines to return with information regarding connection to the electricity grid and that connection costs are more standardised. Also that renewable electricity generation plants such as AD plants are connected promptly, so to reduce detrimental economic effects.

The RHI for direct heat production is set currently for very low generation rate and therefore not useful to the large majority of the plants. For gas grid injection, oxygen levels requirements should be addressed to allow a slightly higher value, accreditation of less expensive but effective monitoring equipment should take place and in the long term a revision of the need for the requirements of such a high CV and Wobbe index for the biomethane could be performed. Some AD operators may welcome the sharing of the gas injection costs/benefits with the gas distribution operator.

There should also be more communication, discussion and integration of the Environment Agency, statutory consultees and the planning authorities, so that the planning process is performed more effectively.

The incentives provided for the producer of biomethane, when used as a vehicle fuel, need to be equivalent to incentives related to gas grid injection and biogas conversion to electricity, otherwise the biofuel route is likely not to be implemented. Supporting the refuelling infrastructure and vehicle costs could also support the developments.

3.0 FACTUAL INFORMATION FOR THE COMMITTEE

In 2009, the AD centre concluded the potential reduction of CO_2 eq. emissions when diverting municipal food waste from a landfill to an AD plant (based on a CHP scenario). Assumptions and results are presented in Table 2.

Table 2 – Summary of assumptions and results if the food wastes generated in Cardiff were diverted from landfill to an AD plant[6]

Population of Cardiff	305,353 (Census, 2001)
Biodegradable waste yield per person per week	2.2 kg
Biogas yield per tonne of wastes	110 m^3
Biogas methane concentration	60%
Electrical conversion efficiency	35%
Electrical parasitic use	20%
Heat conversion efficiency	50%
Heat parasitic use	50%
CO_2 emission factor from electricity generation	430 kg/MWh (DEFRA, 2007)
CO_2 emission factor from combusting natural gas	190 kg/MWh (Carbon Trust, 2009)
Conversion factors for methane	21 x CO_2 potential (DEFRA, 2007)
CO_2 emissions per capita in Cardiff (2005-2006)	7.2 tonnes (Defra, 2008 - report by AEA)
Landfill methane capture	70%
CO_2 Emissions avoided by diverting the waste from landfill to an AD plant over 25 years	718,982 tonnes
CO_2 emissions displaced from renewable electricity and heat exported by the AD plant over 25 years	96,504 tonnes
Total CO_2 emission reduction: **815,486 tonnes**, equivalent to 4531 people CO_2 emissions for 25 years ~ 1.5 % of Cardiff's population	

Later, DECC stated that digesting 1 tonne of food waste rather than sending it to landfill would save between 0.5 – 1.0 tonnes of CO_2 equivalent[7]. DECC's assessment seem to corroborate previous AD Centre analysis.

Typically, assuming an electrical conversion of 36% and a 50% heat conversion, each tonne of food wastes can yield approximately 236.8 kWh of electricity and 329 kWh of heat, based on a CHP scenario. The same waste can power a car for approximately 1000 km, instead.

The AD Centre has also performed an initial assessment of the energy utilised in the collection and transport of municipal food wastes to centralised AD facilities compared to the inherent energy content within the food wastes. Figure 2 shows that only at 553 miles round trip (collection of wastes and transport of digestate) there is a zero net gain from the energy intrinsic to the food wastes (included was already the energy used for the treatment process). This does not in any way indicate that this mileage related to the transport of wastes and digestates should be a common practice. It would certainly be of benefit to have minimal mileages, both from an environmental as well as an economic point of view. However, the size of a facility is also important in terms of economics and can also impact on the owner/operator ability to minimise impacts and therefore maximise the plant's environmental benefits.

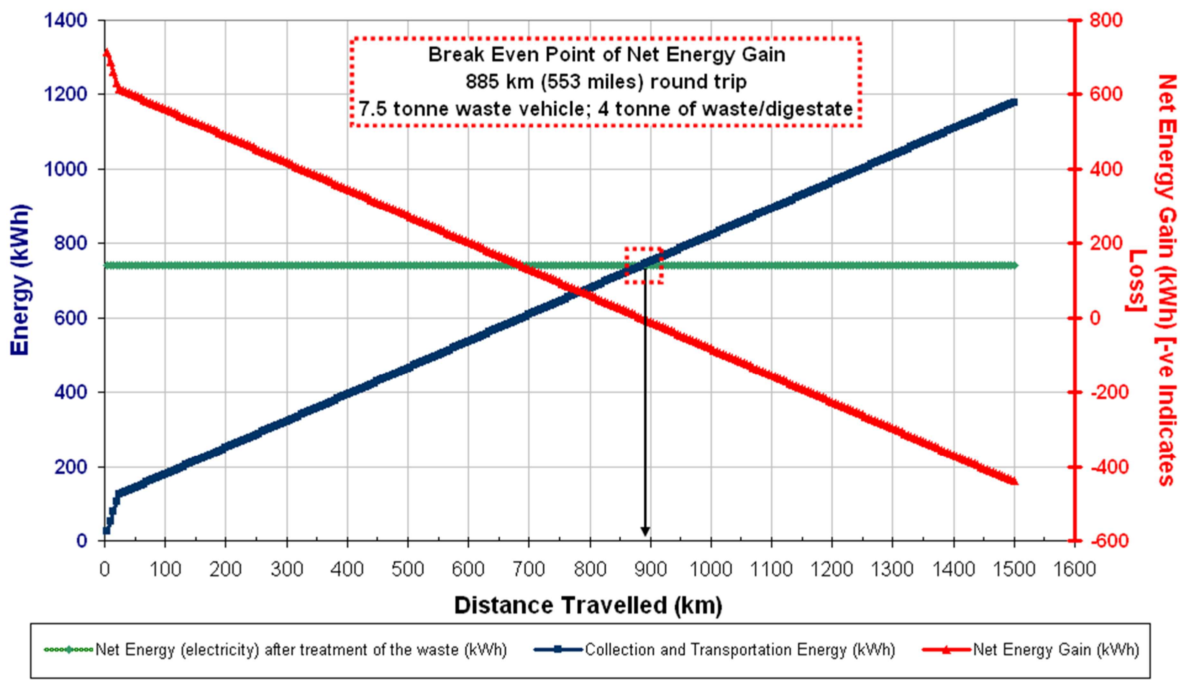

Figure 2 - Collection and transport energy for biodegradable municipal waste and digestates compared to net energy (electricity) from AD (CHP scenario)[6]

Assuming:

- 7.5 tonne vehicle carrying 4 tonne waste (same for digestate)
- Diesel consumption for collection (2 km/l) for 20 km; Diesel consumption for transport (15 km/l) to plant
- 1 tonne of BMW generates 110 m^3 of biogas (60% methane)
- Electricity generation efficiency (35%) and 20% parasitic load
- No export of heat (only 50% of the heat generated is consumed within the plant)

The AD centre has also completed a life cycle assessment of potential biogas infrastructures for the treatment of source segregated municipal food wastes on a regional scale in Wales[8]. The study compared the environmental impacts, across a broad range of impact categories, associated with the construction and operation of AD plants treating source segregated municipal food waste and the utilisation of biogas for either CHP, or injection to the gas grid for end use as either transportation fuel or domestic heat. The paper also assessed whether there were significant environmental benefits from developing a centralised or more distributed infrastructure on a regional basis.

Centralised (comprising of 5 No. medium / large AD plants) and distributed (comprising of 11 No. small / medium AD plants) infrastructures were considered along with biogas end uses of Combined Heat and Power (CHP) and injection to the gas grid for either transport fuel or domestic heating end uses. The assessment was based on the treatment of a total of 275,900 tonnes per annum of source segregated municipal food waste.

Utilisation of biogas for domestic heating purposes via the gas grid displaces the most fossil fuel in both the centralised and distributed infrastructures (6.10×10^7 MJ and 6.60×10^7 MJ, respectively) closely followed by transport fuel use (5.83×10^7 MJ and 6.34×10^7 MJ) and CHP with 80% heat utilisation (5.48×10^7 MJ and 6.04×10^7 MJ). Not surprisingly, CHP with 0% heat utilisation was the worst performing in terms of fossil fuel displacement (1.46×10^7 MJ and 2.02×10^7 MJ) (Figure 3).

The CHP scenarios show the importance of utilising the surplus heat generated when converting biogas to electricity in combustion engines. The scenario with 0% heat utilisation stands out as performing worst compared to other options, whereas the scenario where 80% of the surplus heat is utilised in an adjacent process performs the best out of all the infrastructures modelled. The additional economic benefits associated with the use of excess heat mean that AD schemes in the UK should be actively seeking to utilise excess heat. Where this high utilisation of excess heat at the end user cannot be achieved, CHP will result in higher impacts than alternative uses such as transport fuel.

The injection of biomethane to the gas grid and its end use for domestic heating was found to offset marginally more fossil fuel than transportation end use, however, the overall impacts associated with the end use were considerably greater. This is because the end use of (biogenic) biomethane for domestic heating replaces the use of (fossil) natural gas which, in the context of the model, would have similar emission concentrations at end use i.e. at the domestic boiler. Therefore, whilst the other end use scenarios are benefiting through reductions in end use emissions by replacing centrally produced electricity or diesel fuel use, the use of biomethane for domestic heating does not incur such benefits. In essence, the emissions at end use are the same whether natural gas or biomethane is used as a fuel. The only savings are therefore those associated with the offsetting of natural gas production and transportation, not emissions at end use.

Given the assumption that the majority of natural gas within the UK grid is used for domestic heating, this result raises the interesting point that whilst the addition of biomethane to the gas grid provides (i) an efficient means of transporting the upgraded biogas, and (ii) corporate advantages associated with the reduction of the carbon footprint of the gas grid, it may not deliver the greatest environmental benefit at this stage. Results suggest that using biomethane to displace more polluting fuels such as liquid fossil fuels will have the greater overall environmental benefit.

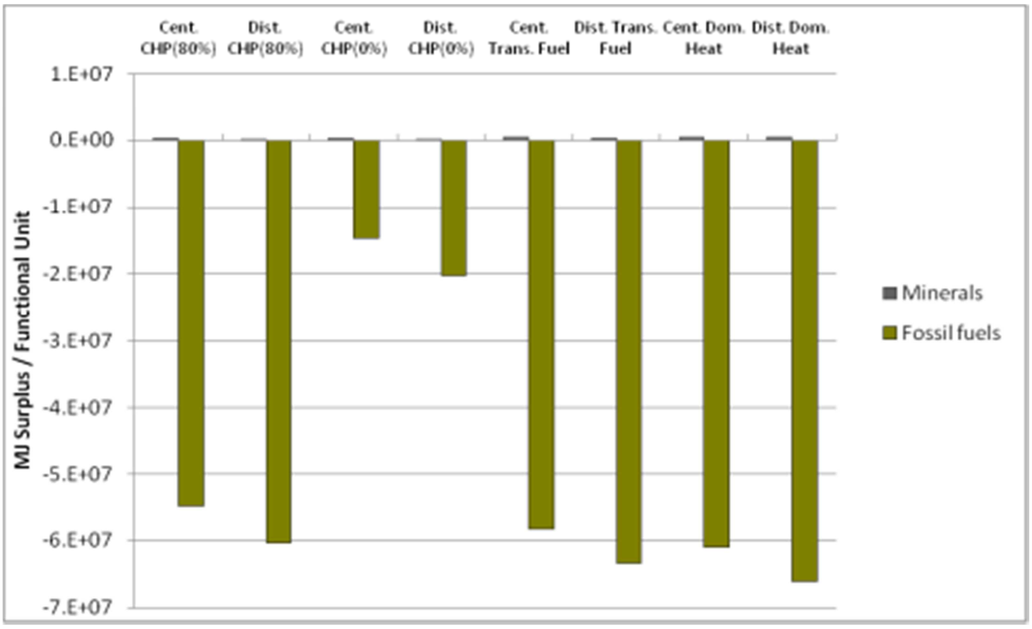

Figure 3 – Fossil fuels and mineral impacts[8]

In 2009-2010, the AD centre analysed the composition of samples of food wastes collected from Welsh homes. Theoretical energy potentials as well as nutrient contents were calculated[9]. The nutrients available in food waste are certainly of significance.

While a number of literature sources report an emission associated per tonne of N produced (through the used of fossil fuels) of around 5 tonnes of CO_2 eq.; Boldrin *et al.* (2009) has stated that 8.9 tonnes of CO_2 eq. are released per tonne of N produced. The same authors reported emissions of 1.8 tonne CO_2 eq./ tonne of P and 0.96 tonnes CO_2 eq./tonne of K. While the production of ammonia has the potential to reduce its impacts and energy consumption in the future, it is very likely that sourcing phosphorus will be significantly more difficult, more expensive and more energy intensive.

See below other correlations between organic resources available in Wales, renewable energy production and potential reductions in CO_2eq. emissions.

In addition to municipal food wastes, there is also in Wales a reasonable supply of commercial and industrial wastes. According to the survey conducted by Urban Mines in 2009, approximately 500,000 tonnes of organic wastes per annum could potentially be available for AD. However, in order to predict biogas potential from these feedstocks, a survey of their composition and organic content would need to be performed in more detail.

One tonne of cattle slurry (wet weight) can yield approximately 43 kWh of electricity and 59.8 kWh of heat; while 1 tonne of dry solids of sewage sludge will convert to 0.8 - 1 MWh of renewable electricity depending on the sludge and the conversion method), plus additional heat. Utilisation of AD to treat dairy slurries can result in a reduction in GHG emissions during storage and field spreading by approximately 59% compared to untreated slurry[10].

In addition to the above waste organic resources, there is also a possibility of utilising agricultural residues such as wheat straw and sugar beet pulp, and energy crops such as fodder beet, whole crop maize, rye grass, sugar beet and sweet sorghum. These could be options that seem to provide good average yields of crops in temperature climates like in Wales and that have also the potential to yield reasonable net energy if digested. Evidence gathering on the energy potential and environmental benefits and impacts of these options is continuing.

4.0 RECOMMENDATIONS FOR THE COMMITTEE TO CONSIDER

A number of recommendations have already been described in the sections above. A summary is here provided.

Size and design of AD plants can differ significantly. AD plants should not be seen as systems that have always the same design or can only operate in certain locations. AD plants have been placed successfully both in industrial as well as rural settings. Proximity to the source of feedstocks and digestate utilisation is certainly important to consider, however other factors such as being served by roads without restrictions to HGVs, as well as reasonable access to the electricity or gas network or to a possible re-fuelling infrastructure for vehicle use are also important consideration factors. It is important that these plants are established and operated within a suitable financial scenario, as this should allow appropriate design and operation methodologies to be followed. These can then be applied to maximise performances, such as through the use of adequate monitoring and control procedures as well as minimisation of plant impacts related to emissions, visual and traffic aspects (see Appendix D), making these plants acceptable neighbours of population centers and even of sensitive environments.

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 recommendations, for which action is required not only by the Welsh Government 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
   - Less restrictive requirements for biomethane injection to the gas grid and the possibility of sharing of costs and benefits between the plant operator and gas distributor should be assessed;

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 the RED, revision for a lower fuel duty should take place, 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. Maintain the renewable energy generation related incentives framework for a number of years without constant alterations;
4. Resist the implementation of the JRC current 'End of Waste Criteria' proposal as it currently stands, namely the solid content requirement for digestates;
5. 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;
6. The implementation of AD to minimise the carbon footprint of the agriculture sector should also be seen as a priority. Capital support for plants treating agriculture residues, if reduction of GHGs are to take place effectively in the UK farming sector;
7. Careful assessment is required 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 would be required;
8. 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;
9. 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;
10. 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, e.g. co-digesting other feedstocks, upgrade biogas collectively with biogas from other AD plants and inject biomethane collectively with biomethane generated at other AD plants;
11. Continue the support to the Wales Centre of Excellence for Anaerobic Digestion;
12. Invest in R&D for improved performance and environmental benefits for the AD supply chain;
13. Support training of stakeholders which influence AD implementation.

5. REFERENCES

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APPENDICES

APPENDIX A

DISSEMINATION EVENTS ORGANISED BY THE AD CENTRE

AD Centre Organised Events

The AD Centre has organised a number of events to disseminate information to a range of stakeholders including industry, local government, regional government and regulators.

Date	Venue	Title	Attendance
18th Sep. 2008	Llandrindod Wells	Anaerobic Digestion: Technology for Biodegradable Municipal Waste Treatment and Energy Production	All Welsh Local Authorities
11th Nov. 2008	Cardiff City Hall	Implementing Anaerobic Digestion in Wales	116 delegates from industry, local and regional government
25th Jun. 2009	Llandrindod Wells	Anaerobic Digestion and the Planning Process	64 delegates from WG and Local Authority planning departments
21st May 2010	WG, Aberystwyth	Anaerobic Digestion – Process, benefits, impacts, mitigation	52 delegates from WG, Environment Agency and CCW and Local Authorities
27th May 2010*	UoG	Training for the Operators of AD plants	10 future operators of AD plants
27th September 2010	WAG Cathays	Introduction to Anaerobic Digestion - Process and Plant Layouts, Benefits, Impacts and Mitigation	WAG's Planning Policy Team
26-27th May 2011*	UoG	Training the Trainers – Inaugural Biomethane Regions Event	39 delegates from Wales, UK and across Europe

* Events organised in collaboration with the Severn Wye Energy Agency

APPENDIX B

PRESENTATIONS MADE BY THE AD CENTRE

Examples Of Workshops/Conferences Presented At In The Last Year

1. Esteves, S., Devlin, D., Dinsdale, R. and Guwy, A. (2011) Methodologies For Assessing Feedstocks and Digestate Batch Anaerobic Biodegradability. 16th European Biosolids & Organic Resources Conference & Exhibition 14-16th November 2011, The Royal Armouries, Leeds, UK
2. Reed J.P., Devlin D., Esteves S.R.R., Dinsdale R. and Guwy A.J. (2011) Lifting The Lid On Process Optimisation For Anaerobic Digestion. 16th European Biosolids & Organic Resources Conference & Exhibition 14-16th November 2011, The Royal Armouries, Leeds, UK
3. Williams H.G., Kumi, P.J., Devlin, D., Williams, J., Dinsdale, R., Esteves, S., Guwy, A. Lawrenson, G. (2011) Squeezing More Energy From Feedstocks: Enzyme Addition And Enzymatic Activity Monitoring. 16th European Biosolids & Organic Resources Conference & Exhibition 14-16th November 2011, The Royal Armouries, Leeds, UK
4. Sandra Esteves. Maximising Anaerobic Digestion Outputs for a Recycling Economy - ADBA annual AD R&D Forum 1st - 2nd November 2011 – Bristol
5. Sandra Esteves, Desmond Devlin, Richard Dinsdale, Alan Guwy (2011) Performance of various methodologies for assessing batch anaerobic biodegradability. International IWA Symposium on anaerobic digestion of solid Wastes and Energy Crops - 28th August – 1st September, 2011 Vienna, Austria.
6. T. Patterson, S Esteves, R. Dinsdale and A. Guwy (2011) Evaluation of the Policy and Economic Factors Affecting the Use of Biomethane as a Transport Fuel in the UK. International IWA Symposium on anaerobic digestion of solid Wastes and Energy Crops - 28th August – 1st September, 2011 Vienna, Austria.
7. T. Patterson, S Esteves, R. Dinsdale and A. Guwy (2011) Life Cycle Assessment of Anaerobic Digestion of Source Segregated Food Waste with Various Biogas End Uses at a Regional Scale. International IWA Symposium on anaerobic digestion of solid Wastes and Energy Crops - 28th August – 1st September, 2011 Vienna, Austria
8. Sandra Esteves. Monitoring and Control Regimes for Keeping the Anaerobic Consortia Happy. UK AD & Biogas Trade Show and Conference 6th July 2011 NEC Birmingham
9. Sandra Esteves. Status of AD/Biogas/Biomethane in England and Wales - Biomethane Regions Project - Kick off Meeting 24-25th May 2011 – Cardiff, South Wales
10. Sandra Esteves. Monitoring and Control Regimes - Inaugural Bio-Methane Regions Event - Training the Trainers 26 - 27th May 2011 - University of Glamorgan, South Wales
11. Sandra Esteves. Introduction to the Anaerobic Digestion Process for Food Wastes and Anaerobic Processes and Biogas Activity at the University of Glamorgan 4th February 2011 – Burges Salmon office (Bristol)
12. Sandra Esteves. Anaerobic Digestion. Seminar CIWM South West and Wales 11th November 2010 – Bristol
13. Desmond Devlin; Sandra Esteves; Richard Dinsdale; Alan Guwy (2010) 'Investigating the Effect of Acid Pretreatment of Waste Activated Sludge on Subsequent Anaerobic Digestion' 12th World congress on Anaerobic Digestion, 31 October 2010 to 04 November 2010, Guadalajara, Mexico

APPENDIX C

PUBLICATIONS PRODUCED BY THE AD CENTRE

Example of Publications

Esteves, S., Devlin, D., Dinsdale, R. and Guwy, A. (2011) Methodologies For Assessing Feedstocks And Digestate Batch Anaerobic Biodegradability. 16th European Biosolids & Organic Resources Conference & Exhibition 14-16th November 2011, The Royal Armouries, Leeds, UK.

Reed, J.P., Devlin, D., Esteves, S.R.R., Dinsdale, R., Guwy, A.J. (2011). Performance parameter prediction for sewage sludge digesters using reflectance FT-NIR spectroscopy. Water Research, 45(8), pp. 2463 – 2472.

Devlin D.C.; Esteves S.R.R.; Dinsdale R M and Guwy A J. (2011) The Effect of Acid Pretreatment on the Anaerobic Digestion and Dewatering of Waste Activated Sludge. Bioresource Technology 102: 4076–4082.

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Patterson, T., Esteves, S., Dinsdale, R., Guwy, A. (2011). An evaluation of the policy and techno-economic factors affecting the potential for biogas upgrading for transport fuel use in the UK. Energy Policy, 39, 1806 – 1816.

Patterson, T., Esteves, S., Dinsdale, R., Guwy, A. (2011). Life Cycle Assessment of Biogas Infrastructure Options on a Regional Scale. Bioresource Technology, 102, 7313 – 7323.

APPENDIX D

COPY OF POWERPOINT SLIDES (S ESTEVES, 2010) SUMMARISING IMPACTS AND MINIMISATION PROCEDURES

Traffic Impact

Food Waste AD Plant Example

- Plant that treats 30,000 tonnes of C&I or municipal waste per year (1.2-1.6 MW electrical output)
- Gate open 5 days a week – 260 days/year
- Waste in (any additional water is from on-site)

  = 7 vehicles daily in and out, if vehicle carries 17 tonne load, **OR**

  = 12 vehicles daily in and out, if vehicle carries 10 tonne load
- Digestate out if no additional water or effluent are included
  - off site storage = 6 vehicles daily in and out, if vehicle carries 20 tonne load, **OR**
  - On-site storage (6 months store) = 12 vehicles daily in and out (6 months only in a year), if vehicle carries 20 tonne load
- Digestate out if 20% additional water or effluents are included (i.e. total substrate for digestion 36,000 tonnes)
  - off site storage = 7 vehicles daily in and out, if vehicle carries 20 tonne load , **OR**
  - On-site storage (6 months store) = 14 vehicles daily in and out (6 months only in a year), if vehicle carries 20 tonne load

Traffic Impact

Agricultural AD plant Example

- Plant that digests animal slurries (20,000 tpa from 1000 animals) and energy crops (10,000 tpa of maize silage from 250 ha) (500 kW electrical output) (gate open 260 days in the year)
- No external transport required for the slurries or crops OR
- Slurries transported using a 20 tonne vehicle load

  = 4 vehicles daily in and out
- Maize silage transported during a 3 week period in the year

  = 44 vehicles in and out during the 3 weeks in the year (Oct- Nov),

  15 tonne vehicle load
- Digestate to be used potentially by the same farms generating the slurries and crops (maximum 30,000 tpa)

  = 6 vehicles daily in and out, 20 tonne tanker

Plant Emissions and Odour Control

- Odours - ammonia, organic acids and sulphur compounds
- Areas – Reception of wastes, pre-treatment and digestate store and processing
- Minimise air emissions, dusts and odours impact
  - Good house keeping and keep building doors closed
  - Enclosed processes, negative pressure in buildings
  - Adequate air renewals – truck sluice, storage, pretreatment, and digestate processing areas
  - Appropriate treatment of substrates

Plant Emissions and Odour Control

- Exhaust gases (from waste reception area, mechanical pre-treatment and post AD maturation areas or digestate storage) require treatment before being released to atmosphere
- Appropriate exhaust gases cleaning – bioscrubbers, chemoscrubbers (NaOH and wet oxidation using sodium hypochloride), biofilters, ozone treatment and/or activated carbon units needs to be installed
- For high ammonia, bioaerosols and VOC levels from the exhaust air of composting hall – a regenerative thermal oxidation (RTO) plant in combination with an acid scrubber may be required for effectively destroys odorous contaminants, bio-aerosols and volatile organics
  - RTO systems are expensive to install and maintain, and are energy intensive)

Emissions and Odour Control Outside the Plant

- Substrate transport enclosed, sealed tankers
- Sealed tankers for liquor digestates
- Digestate storage tanks covered
- No spreading of digestates, shallow injection will minimise odours