05-03: Cost structure in systems based on digestible/fermentable biomass

Anaerobic digestion plants generate gas from a range of organic materials which is then used to produce either heat or heat and power. The development of such projects needs to consider a number of key issues when examining the financial viability
Key resources to be used as raw material for the digestion process
Scale of plant and energy output (heat, heat & power etc)
Technology to be utilised (mesophilic, thermophilic etc)
System O&M costs

Each of the above will be considered in the following chapters.

A large number of projects have been financed by the European Federation within different research programmes, "Intelligent Energy for Europe" and "Bioenaea" only to mention two of them. Among the projects you will find good examples, case studies and tools to make a reasonable economic analysis.
Int. En: https://ec.europa.eu/energy/intelligent/projects/en/node?page=1
Bioenarea: http://www.bioenarea.eu/node/199

05-03-01 Elements important for the cost of the substrate

As outlined in the Chapters 02_03 the variety of materials which can be utilised for in a digestion/fermentation process are considerable. The key characteristics which will affect the cost element of the resource to be used are:

- Source of materials (on-site, purchased etc)
- Category of materials (residue, hazardous etc)
- Energy content

The mix of materials used will affect the gas output of the AD plant and therefore the energy generation. The move towards AD plants which use silage or similar materials is driven by the fact that high gas yields are available and therefore greater energy sales are possible per m^3 of material treated.

05-03-01a Agricultural Substrates

A large majority of anaerobic digestion plants will utilise agricultural substrates within their process. These can include manures, grass, energy crops etc. In general, the materials with the higher gas yields could have an increased cost per m^3 if they are to be purchased.

- Manures: In practically all cases there should be no cost associated with the use of manures as a raw material. For farm scale plants the manures will require storage but in many cases such storage is required as part of environmental requirements anyway so limited additional costs may be incurred. For centralised plants there will be

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transport costs associated with moving the manures from the farms to the centralised plants. However, in many cases these costs are negated by the costs associated with moving the digestate from the AD plant for use of the farms.

- Grass/Maize: where grass/maize or other crops are grown for use in an AD plant there will be costs associated with the crop production (ground preparation, sowing, fertilising, harvesting). The costs per tonne will vary depending on local conditions and costs.

In the majority of cases the costs of using agricultural substrates the cost per tonne can be taken as 0 for initial feasibility.

However, in most cases the materials are either a waste/residue which the AD plant can take in for free or potentially charge a gate fee.

The gate fee which can be charged should be related to the gas yield of the material. The cost can vary from €10 to 200/tonne depending on the material being imported.

05-03-02 Elements making up the total cost

The cost of developing the AD plant will depend on

- Size of AD digester and associated storage
- Size of energy generation plant (heat only or CHP plant)
- Environmental control systems (air, water, noise etc.)
- Grid connection (where applicable)
- Material segregation

An analysis by the Irish Environmental Protection Agency perofrormed during 2005 evaluated the financing of a centralised anaerobic digester in Ireland. This analysis was carried out with reference to detailed data on the operating costs and statistics of a number of centralised AD plants in Denmark.

In this study, the following assumptions were made:

- Co-digestion with agricultural slurries with an assumed 80:20 ratio of agricultural and non-agricultural wastes.
- Biogas production yield assumed to be 40m^3 per tonne.
- A price of €0.08/kWh for electricity produced, (the 2010 REFIT scheme has increased the price offered for electricity produced from AD substantially – see above).
- A gate fee of €60/tonne on non-agricultural wastes.
- Operating costs estimated at €15/tonne.
- A 5% interest rate and a 15 year investment period.
- Adjusted Net Present Value figure taking account a 50% capital grant.

Based on these assumptions, financial outcomes for three hypothetical AD plants are presented in Table 05-03 1 below.

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AD Plant	Unit	A	B	C
Wastes Intake	tonne/day	187.5	312.5	500.0
- Agricultural (80%)	tonne/day	150.0	250.0	400.0
- Non-agricultural (20%)	tonne/day	37.5	62.5	100.0
Gas Production	tonne/day	2.74	4.56	7.30
Electricity Generation	GW	5.02	8.36	13.38
Non-Agricultural waste intake fees	€m	0.89	1.48	2.37
Electricity Revenue	€m	0.40	0.67	1.07
Operating Costs	€m	1.03	1.71	2.74
Plant Infrastructure Cost	€m	3.38	5.63	9.00
Tanker & Storage Cost	€m	0.56	0.94	1.50
Net Present Value (NPV)	€m	-1.80	-3.01	-4.81
NPV (inc. 50% grant on plant and storage)	€m	0.53	0.88	1.41

Table 05-03 1 – **three hypothetical AD plants.**

From table 05_03 1 it is clear the dominant element of cost make up is the capital investment. On this basis one must account for this major barrier in the current strained financial market. With a NPV of 50% including grant then the importance of good renewable feed in tariff supports is key.

An analysis by the Irish Environmental Protection Agency perofrormed during 2005 evaluated the financing of a centralised anaerobic digester in Ireland. This analysis was carried out with reference to detailed data on the operating costs and statistics of a number of centralised AD plants in Denmark. The following table shows a summary of some key data from a study performed by the Danish Biogas Association in 2000. The study concerned the investment cost structure in a large number of centralised AD plants. The values are of course only indicative but they serve to illustrate the ranges and the proportions between costs.

	Per day treatment capacity		
Investments Costs (m€)	**300m^3**	**550 m^3**	**800 m^3**
Biogas Plant	**5.5**	**7.9**	**9.6**
Vehicles	**0.4**	**0.6**	**1**
Investment Cost per m^3 biomass treated per year (€/m^3)	**55**	**44**	**37**
Treatment cost per m^3 biomass treated per year (€/m^3)			
Transport	**2.2**	**2.2**	**2.4**
Biogas plant	**7.1**	**7.7**	**4.7**

Table 05-03 2 **Danish Biogas Association Review of AD investment costs (2000)**

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05-03-03 Case studies

05-03-03a Farm scale AD plant, Germany

http://www.walesadcentre.org.uk/Controls/Document/Docs/Greimel%20Biogas%20Plant,%20Bavaria%20(FINAL).pdf

Capital costs for the plant are understood to have been approximately 3.5 million Euro. Tariffs for the energy generated at the plant are per the EEG2009. The tariffs generated at the plant are below:

EEG 2009 Tariff	Cent / kWh_e (or kWh_{th} if stated)
Basic Compensation (up to 150kW)	11.67
Basic Compensation (150 - 500 kW)	9.18
Basic Compensation (500 – 1500 kW)	8.25
Clean Air Bonus	1
Energy Crop Bonus	7 up to 150 kW & 4 from 500kW up to 5 MW
Manure Bonus	400 up to 150 kW & from 150kW up to 500 kW
Heat Utilisation Bonus	3.0 kWh_{th}
Digression	1.00%

Table 05-03 3 **Tariffs generated at AD Plant, Germany**

Each kWh of electricity generated at the site would therefore attract a total tariff of 21-22 Euro Cents giving a gross income of approximately 1 700 000 Euros per year, and each kWh of heat would attract a further 3 Euro Cents giving a potential gross income of 270 000 Euros per year.

05-03-03b Centrally Segregated AD Plant

http://www.walesadcentre.org.uk/Controls/Document/Docs/Pohlsche%20Heide_Comp__F.pdf

The Pohlsche Heide MBT plant and wastes treatment centre is located at a landfill site between the towns of Hille and Minden, on the northern boundary of the Minden- Lübbecke district. The plant generates electricity and heat for use on site in the waste treatment centre.

COSTS AND ECONOMICS

The MBT plant cost a total of €26 million. It was estimated by a Dranco representative on-site (Six, Personal Communication, 2005) that the Dranco reactor and the biogas cleaning and utilisation equipment cost approximately €6.4 million of this. Operational costs (excluding RDF disposal) were stated as €60 per tonne, with the gate fee received being €125 - 145 per tonne. The low water usage and wastewater treatment requirement contributes to keeping the operational cost down.

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As the plant covers the vast majority of its energy requirements, energy costs will be low, although as no energy is exported, there is no income for this.

05-03-03c Landfill and AD plant

http://www.walesadcentre.org.uk/Controls/Document/Docs/Kahlenberg_Comp__F.pdf

The plant is owned and operated by ZAK (Zweckverband Abfallbehandlung Kahlenberg), which is the regional municipally owned waste handling company. The planning and the management of the building of the new site were carried out by ZAK, with the individual areas of expertise sub-contracted to companies with specific areas of expertise.

The ZAK Ringsheim plant is currently the only one of its kind in the world.

COSTS AND ECONOMICS
The total capital cost of the plant was €45 million (Gibis, Personal Communication, 2006). Operating cost per tonne of incoming waste is €70 (including finance). It is assumed that the incomes from the excess electricity and heat produced are included in this figure. As the plant is publicly owned, the gate fee charged is slightly above €70/tonne. ZAK are confident that their 'concept' represents the best possible residual wastes solution given German Legislation, but accepts that it may be an elaborate and expensive option in other nations given the less strict Legislation.

05-03-03d Landfill and AD plant

http://www.walesadcentre.org.uk/Controls/Document/Docs/Heilbronn_Comp__F.pdf

The Heilbronn MBT plant was built by ISKA GmbH. ISKA GmbH is a subsidiary of U-Plus Umwelt Service AG, which is one of the biggest waste disposal companies in Germany. The plant is also owned and operated by U-Plus UmweltService AG who have the long term contract to treat municipal residual wastes in the area. Plant capacity is 88 000 tonnes per annnum (tpa), and currently around 80 000 tpa is accepted. The plant processes the residual waste from approximately 625 000 inhabitants in the city of Heilbronn and 2 surrounding rural districts

COSTS AND ECONOMICS
The capital cost of the whole MBT plant was approximately €27 million. The landfill site is owned by the region, and ISKA currently pay €53/tonne to dispose of their biostabilised output. Payback time was estimated at 15 years, at current prices, but increased gate fees would reduce this, and increased landfill charges would increase it. The cost of the project was increased slightly due to the limited space available, and severely due to the proximity of the site to a river. The site also suffers significantly (as compared to the Buchen site) in terms of extra costs due to its smaller throughput (€338 / tonne compared to €278 / tonne in terms of capital costs). Operating costs were estimated at €35 – 55/tonne (including finance), as at Buchen, approximately half was spent on exhaust air treatment (Kutterer, Personal

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Communication, 2006). Exhaust air treatment legislation in Germany is particularly stringent, and in the UK this would not represent such an expense. As mentioned in the Buchen case study, the incinerator is also owned by ISKA.

05-03-03e AD and Vehicle Fuel

http://www.walesadcentre.org.uk/Controls/Document/Docs/Vasteras_comp__F.pdf

The Växtkraft biogas plant is situated adjacent to the other installations at the waste treatment plant at Gryta, in the northern outskirts of Västerås. Västerås (in Västmanland county), is Sweden's sixth biggest city and has around 140 000 inhabitants in the extended area. The Växtkraft biogas plant has a total throughput of 23 000 tpa, comprising of 14 000 tpa of source separated municipal kitchen waste, 4 000 tpa of grease trap removal sludge and 5 000 tpa of specially grown energy crops. The plant was planned and built, and is operated by Svensk Växtkraft, which was a company set up specifically to oversee the project.

COSTS AND ECONOMICS

The total capital cost for the biogas plant was in the region of €8.4 million. The contract was a 'turn-key' contract, which means that everything from the initial ground work to the plant running at the levels stated in the contract (Persson, Personal Communication, 2006). The total capital cost for the gas upgrading plant was €1.7 million. The contract was similar to that for the biogas plant, meaning that everything was included, and the contract was not complete until the plant had been running successfully to pre-stipulated performance levels for a stated period of time. The total capital cost for the facilities at the bus depot (high pressure compressors, high pressure gas storage, LNG storage, tank stations for buses and cars, including buildings and internal gas piping *etc*.) cost a total of €1.4 million (Persson, Personal Communication, 2006). The plant was co-funded by EU FP5 program for research and demonstration, by the Swedish government and by the conglomerate of investors described above. The funding was as follows:

- 30% by EU.
- 30% by Swedish Government.
- 40% by the Conglomerate of investors who own the plant.

The 40% share provided by the owning partnership was based on finance from financial institutions, whose reactions to the application varied greatly. The risk perceived by the banks was reduced greatly by the size of the participating companies for example, the energy company (Mälarenergi), wastes and water companies (Vafab-Miljö).

As part of the Agropti Gas project a socio-economic analysis report was carried out (JTI, 2006). To summarise the findings of the socio-economic analysis, the system as it stands is a win-win situation. The results for the annual benefits are summarised below:

- Benefit to the environment was estimated at €91 930.
- Benefit to society was estimated at €275 781.
- Benefit to agriculture was estimated at €72 000.
- **Total Benefit = €439 970**.

Other benefits not factored into these figures include;

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- Increased opportunities for rural employment.
- Positive impact on working environments.

- Increased levels of health (as emissions of ammonia and VOCs are reduced, as well as particulates, CO_2 and NO_x reductions from the substituting of diesel as a transport fuel).

A negative impact is the compaction of the soil when spreading the solid digestate or liquid fertiliser. Another area that needs more work was the storage facilities for digestate (solid and liquid), which currently lead to ammonia loss.

05-03-03f Farm Scale Ireland

GreenGas Anaerobic Digestion Plant was commissioned in early 2011 by the O'Donnell's. In early 2012 it began running 24/7. It is a mesophilic plant. It was installed to utilize the dairy and poultry waste available from the separate business of farming. 90% of energy produced is exported to the grid at a rate of €0.15 per kWh.

The capital cost was €1.4 million; this does not include the land cost. SEAI provided a grant of €400 000. The maintenance and operating costs are €40 000 per annum. Average gate fees charged are €80 per tonne (range €40 - €120/tonne).

Original Capital cost	€1 400 000
SEAI Grant	€400 000
Actual Capital cost	€1 000 000

Annual Energy Output (kWh/yr)	1 971 000
Gross income from energy sales per annum (@ €0.015 / kW/h)	€295 650
Estimated income from gate fee's	€8 000

Simple payback

Gross income	€303 650
Interest (5% over 6 years) per annum	- €11 667
Maintenance & operating costs (CPH is the main contributor)	- €40 000
Compliance & local authority charges	- €10 000
Net income	€241 983

Capital Costs	€1 400 000
Net income from energy sales per annum	€241 983
Payback period	5.79

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(GreenGas 2012) [2]

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