Lintrup (LinkoGas) Biogas Plant

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CASE STUDY – OTHER AD WASTE TREATMENT SYSTEMS

Lintrup (LinkoGas) Biogas Plant

INTRODUCTION

The LinkoGas Biogas Plant (near Lintrup, Denmark) treats approximately 200,000 tpa of organic wastes. LinkoGas A.m.b.a is an independent co-operative society set up by 60 local farmers, who supply the slurry which makes up the majority of the waste entering the plant. The main aim of LinkoGas A.m.b.a is to build and operate a manure-based centralised co-digestion plant. Its primary aim (or driver) was assisting the co-operative members (farmers) to meet their legal demands with regards to slurry storage and handling. The reduction of the odour nuisance from slurry application to land was also a main driver. The plant was built in 1989 – 1990, and rebuilt in 1999 when the plant was converted from mesophilic to thermophilic operation. The rebuilding also incorporated a post-digestion phase. The plant receives a total of approximately 200,000 tpa of biowastes, making it one of the largest biogas plants in the world. The incoming biowaste consists mainly of manure (approximately 150,000 tpa), which contains 62% cattle manure and 38% pig slurry. The manure is produced on the surrounding farms, which are all within a 7 km radius of the plant. The plant also receives approximately 50,000 tpa of 'alternative biomass', for which it receives a gate fee. The 'alternative biomass' includes sewage sludge, glycerol from biodiesel production, slaughterhouse waste and hospital food waste. The hospital food waste has been treated mechanically to remove non-organic contaminants, and pressure sterilised before it arrives on site (so no extra pre-treatment is necessary). No exact figures for the composition and quantities of the incoming waste were provided. The plant was built by Krüger and Bioscan.

LinkoGas has 8 employees in total. Four of these are tanker drivers. The manager and assistant manager operate more like foremen, with a 'hands on' approach, and there are two maintenance engineers. Staff work Monday to Friday. The plant is run automatically under normal circumstances, and should problems arise 'after hours' the manager or assistant manager are paged and respond immediately. They take it in turns, one week on, one week off, to be on-call after hours.

PLANT DESCRIPTION

A (very) simplified process flow diagram is shown in Figure 1.

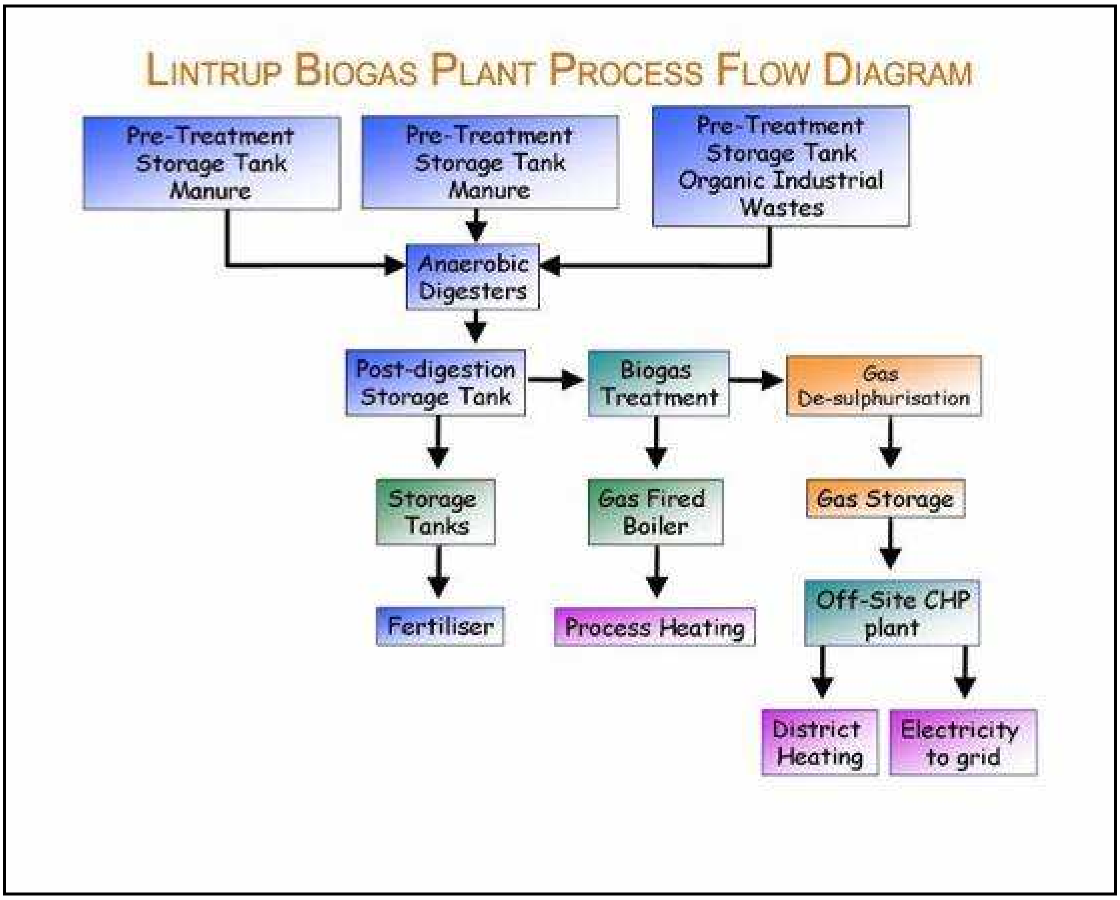

Figure 1 Lintrup Biogas Plant process flow diagram

PRE-TREATMENT DESCRIPTION

After being weighed on the weighbridge, the waste is emptied from the collection vehicles into one of three wastes reception pits. Each wastes reception pit has a volume of 800m^3. Two of these pits receive manure, and one receives industrial organic wastes. This separate storage of incoming wastes means that the exact characteristics of waste passed to the digesters can be manipulated in order to promote process stability.

The wastes reception hall is the building on the left. The offices and workshops are in the low building on the right, behind the biogas flare. Two of the three digesters can be observed between the two buildings (Figure 2). Figure 3 shows the inside of the wastes reception hall, with a vehicle offloading industrial organic wastes into one of the wastes reception tanks.

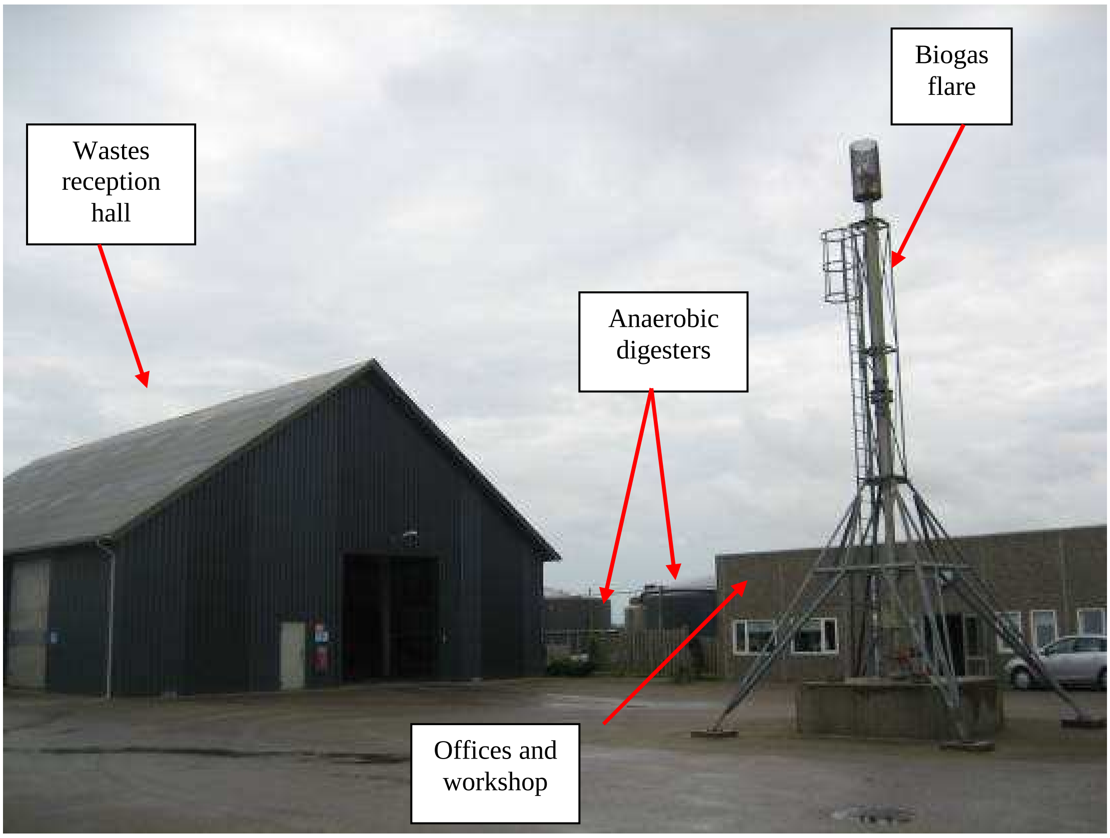

Figure 2 Wastes reception hall

Figure 3 Inside wastes reception hall

Figure 4 shows one of the wastes reception tanks from outside. As can be seen the bulk of the tank is underground, which minimises visual impact. This is the same tank into which the tanker is emptying waste (Figure 3).

Figure 4 Wastes reception tank

ANAEROBIC DIGESTION

The digesters are continuously fed, 24/7, and the storage tanks are large enough to cover bank holiday weekends with no waste deliveries. There are three digesters, each with a volume of 2,400 m^3. The digesters operate in the thermophilic temperature range at 55^{o}C. Two of the digesters are mixed by paddles attached to a vertical shaft. The third is mixed by a central vertical tube containing a pump, which sucks liquid in from the top and pumps it out the bottom, causing a circulation flow pattern from the bottom, around the edges and to the top of the digester. Experience and results have shown this mixing method to be far superior that the other type of mixing (Christiansen, Personal Communication, 2006). Also, the digesters are short and wide, which was considered 'state of the art' at the time of construction. Nowadays digesters tend to be taller and narrower, to allow for better mixing, process dynamics and efficiency. Digestion is wet, with a % TS content of 7 - 8% in the reactor and average retention time is 13 days. The minimum retention time can be guaranteed at 12 days, which at the process temperature of 53^{o}C provides a pathogen reduction equivalent to pasteurisation (LinkoGas Promotional Information). Process heat is supplied by a biogas and oil fired boiler on site. The digestate also passes through heat exchangers after digestion, to maximise the heat transfer between outgoing and incoming waste, and keep to a minimum the volumes of biogas/oil that need to be used. Temperature, gas production, gas pressure and liquid levels are currently measured on-line. A methane content monitor will be coming on-line soon.

Liquid samples are taken once per week for pH and VFA analysis. Liquid samples are taken more regularly if the on-line data is showing any irregularities. The plant manager has (and is in the process of) setting up research projects in conjunction with Danish universities. As well as supporting research that will hopefully lead to scientific advancement, and improvements in process efficiency. These projects will serve to provide the plant with continuous on- and off-line data that will provide greater insight into the digestion processes and dynamics. As described below the more data that is available, the more the process can be optimised, and LinkoGas fully realise the potential (Christiansen, Personal Communication, 2006).

Figure 5 Anaerobic digester at Lintrup

The digester operates steadily in a pH range of 8.0 – 8.3, but is almost always around 8.2. No chemical additions are required to maintain this. The incoming waste is received based on contracts with industries, so it is received regularly, and the feeding pattern to the digester is kept as constant as possible.

Sedimentation of sand or other small inerts has not yet been a problem in the digesters, although it is expected that the bottom of the reactor will contain an ever increasing layer of settled inerts. Despite taking up space in the digester, and therefore minimising the active volume and lowering throughput capacity, these inerts have not yet caused any operational problems. Once they reach levels that do cause problems however, there is no mechanism in place to remove them. As reactors have been operating since 1990 it can be said that sedimentation does not represent a major problem (although perhaps at some point in the digesters working life it will).

POST AD TREATMENT

The post-digestion phase at Lintrup is in effect another anaerobic digester, operating in series with the first three digesters, which all feed into it. It doubles as a storage tank, but as temperature is kept at 49°C, digestion is still occurring and biogas is produced and harvested. LinkoGas have plans to convert this post-digestion storage tank to another thermophilic digester. Lab-scale tests done on behalf of LinkoGas by a Danish University show that a 25% increase in biogas production will be possible by making this change.

FINAL SOLID PRODUCTS

The digestate is stored in underground storage tanks on site (Figure 6), before being transported by tanker back to one of 128 de-centralised storage tanks on the farms of the partners from which the slurry originated. The de-centralised storage tanks are located in the fields on which the digestate will be spread. The slurry suppliers receive the amount of digestate corresponding to the nutrient consumption of their crops. The surplus, around 15% of the digestate, is sold to 20 crop farms in the area (LinkoGas Promotional Information).

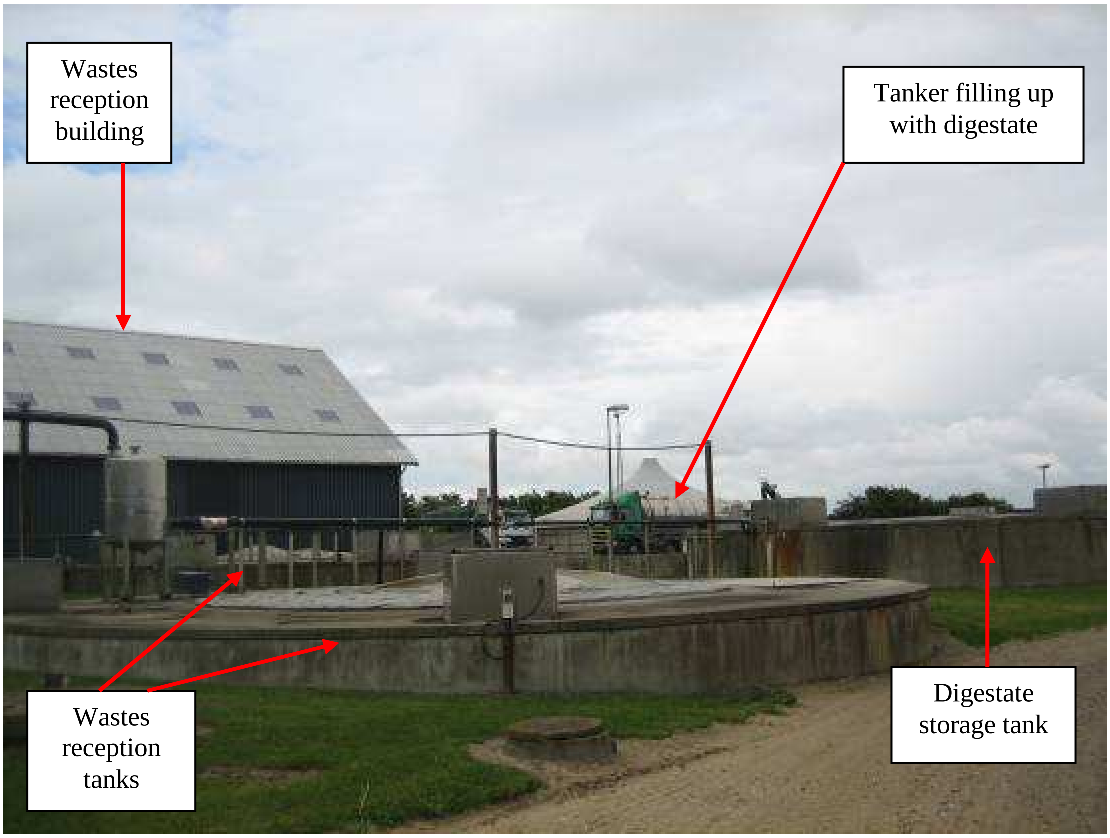

Figure 6 Digestate storage tanks

In Figure 6 a tanker can be observed collecting the digestate for delivery to the farms. The quality of the digestate is extensively tested once every three months by independent laboratories. Heavy metal levels, pathogen levels and N:P:K levels are tested and documented as part of a quality assurance scheme.

A Danish University has recently completed a study on whether or not it would be beneficial to de-water the digestate before it was transported back to the farms. The conclusions were not discussed other than the fact that de-watering was found to be unnecessary at present. The farms would be the final destination for both the solid and liquid fractions anyway, so separating them would be of little benefit in this case.

WATER USE AND WASTEWATER TREATMENT

The plant does not use any fresh water, other than for washing down the wastes reception hall. The incoming wastes have enough moisture content to mean that no water addition is necessary. Similarly, as the digestate is stored on-site before being transported the short distance back to the de-centralised on-farm storage by tanker, no wastewater is produced and there is no need for wastewater treatment.

BIOGAS UTILISATION

The plant produces approximately 6 million m^3 of biogas per year. This represents approximately 30 m^3/tonne of organic waste incoming. This figure is low because of the high amounts of slurry treated, and its comparatively low biogas potential. Biogas is de-sulphurised on site (Figure 7). A small portion of the biogas is retained on-site to fire a combined biogas and oil boiler (0.9 MW), which provides the heat required on-site. The rest of the biogas is stored in a biogas storage tank with a volume of 5,000 m^3 (which can also be seen in Figure 7), and piped via a low pressure gas transmission system to the nearby Rødding CHP plant. At the CHP plant the biogas is utilised in two biogas engines to produce electricity (maximum 2084 kW) and heat (maximum 2,600 kW), which is used in a district heating scheme. There is also a pressurised gas storage tank on-site (also in Figure 7), where gas is stored if the Rødding CHP plant can not accept the gas or is running below capacity due to maintenance. This pressurised gas storage tank is a safety measure, and is rarely used. There is also a biogas flare on-site (Figure 2) as a safety measure. The biogas is sold to the CHP plant, which in turn sells the electricity to electricity providers at a green tariff, and sells the heat to the 'town'. The costs for the installation of the district heating scheme were met by the local municipality after a long term contract for the supply of the heat had been agreed in principle.

The emergency gas storage tank is in the foreground, and the dome-shaped gas buffer tank in the background. The taller grey unit is the biogas de-sulphurisation unit. This unit has just been installed and the old de-sulphurisation unit is lying beside the new one, awaiting removal.

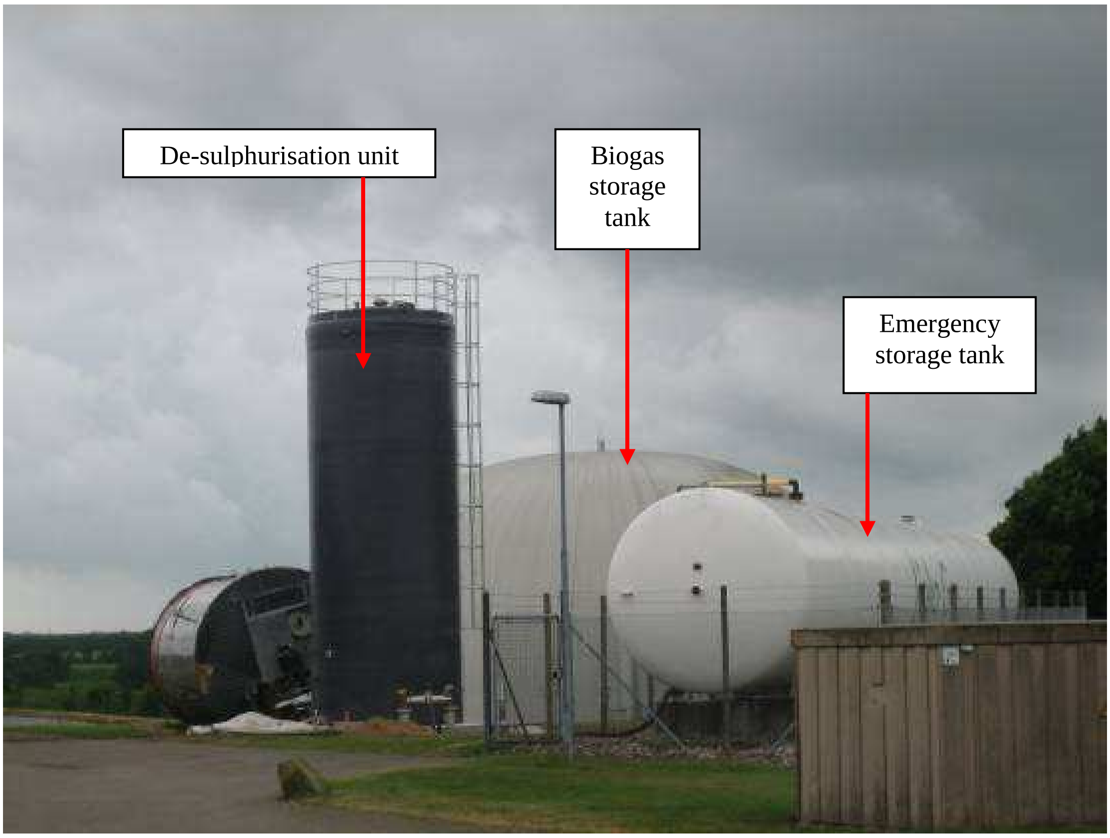

Figure 7 Biogas buffer/storage tank, emergency storage tank and de-sulphurisation unit

ENERGY PRODUCTION

From the biogas produced at Lintrup 13,000 MWh/year of electricity was produced in 2005 (LinkoGas Promotional Information). This electricity production will have produced a large amount of heat energy as a by-product.

EXHAUST GAS TREATMENT

Approximately1000 m^3/hour of exhaust gases and reception hall air is treated in a thermal oxidation unit on-site.

COSTS AND ECONOMICS

The plant was started up in 1990. The total investment cost for the plant (including the off-site storage capacity) was 43.6 million DKK (£4.1 million, or €5.5 million, using January 1990 exchange rates). A Government grant of 16.8 million DKK was awarded (£1.57 million, or €2.12 million, using January 1990 exchange rates).

From the biogas produced at Lintrup 13 million kWh/a (13,000 MWh/a) of electricity was produced in 2005 (LinkoGas Promotional Information). At current UK prices (£107.50/MWh of electricity from biomass, NFPA website, accessed September 2006) this would be worth £1,397,500. The plant also receives gate fees for the industrial organic waste received for treatment. The operating cost was quoted as around €7.5/tonne, including transportation, maintenance, and wages (Christiansen, Personal Communication, 2006). No more information on plant economics was made available.

VISUAL AND LOCAL IMPACT

Considering the scale of the plant (200,000 tpa) it is surprisingly compact and inconspicuous (Figure 8). The tallest structure on site is probably the digesters or the chimney from the thermal treatment of exhaust gases. Both of these structures have approximate height of 15 m. The wastes reception tanks, and the digestate storage tanks are all underground, as is most of the piping, which considerably reduces the visual impact of the site.

Figure 8 Lintrup Biogas Plant

The plant looks similar to the many high intensity agricultural operations in the area. Figure 9 shows a pig farm across the road from the LinkoGas site, owned by one of the participating farmers.

Figure 9 Pig farm in Lintrup

Odour control, and keeping emissions to a minimum has been given priority status in Denmark, due to the perceived importance of the image of anaerobic digestion plants. Previously, the site received many complaints about odour, especially in the summer. The Lintrup plant now uses thermal oxidation to minimise odours. Approximately 1000 m^3/hour of exhaust gases from various parts of the plant are treated by thermal oxidation. A biofilter would have been a much cheaper option, and would probably have been sufficient to meet the legislation (Christiansen, Personal Communication, 2006), but the thermal oxidation system was chosen as the plant wanted to emit no odours. More emphasis than usual was probably placed on odour reduction considering the plant was locally owned, by farmers who lived within 7km of the plant. Some odour was detectable outside the buildings on the plant. Unsurprisingly, the plant smelt of manure, although the level of the odour was no worse than any farm, and was certainly not unacceptable.

CHALLENGES AND DISCUSSION

The digesters were 'state of the art' at the time the plant was built (1989). These days experience has shown that taller, narrower digesters allow for better mixing, process dynamics and efficiency. Therefore if the plant was to be rebuilt, a different digester design would be used. The stirring/mixing efficiency was found to be vastly superior in the 3rd digester, which operated on the circular pattern pumping, as compared to the first two digesters which were stirred by a vertical shaft from the centre of the top of the reactor, with attached paddles.

Occasionally, the analysis of incoming waste streams reveals that the waste exceeds the 'consent' limits for contaminants. All waste being received is tightly specified, and if it is found to exceed the contractually agreed limits, it is refused. This is not a problem for the plant, as they are entitled to refuse waste that could compromise the process or the quality of the digestate, but is a problem for the waste producers, as they must quickly remedy the problem or face the ongoing expense of finding an alternative disposal route.

The retention time in the anaerobic digesters at the time of the visit was 13 days. The retention time is low because of the high throughput. The plant manager would like to have a retention time of at least 16 days, to ensure that the maximum possible biogas yield is obtained. It is in these situations, where the plant accepts the maximum possible amount of waste, and changes to the process would be prohibitively expensive that process optimisation (and getting the depth of data and knowledge to enable optimisation) becomes a very attractive proposition. The future conversion of the post-AD storage tank to another thermophilic digester will help to optimise the system further, adding to the digestion time and biogas yield.

Biogas plants in Denmark have traditionally been managed more ‘by experience by technical foremen’, rather than ‘scientifically by educated managers’ (Christiansen, Personal Communication, 2006). Things are changing now, and a new breed of managers are emerging who recognise the fact that the anaerobic digesters are a living culture, rather than a machine. The current trend in Denmark, with its many centralised AD plants, is to have ‘technical foremen/site managers’ on-site, but to have more educated biogas plant managers overseeing the operation of 6 – 7 plants in the same area. Since taking over the management of the plant in 2004 Aage Sig Christiansen has increased the biogas production by 30% (Christiansen, Personal Communication, 2006). Key to this increase in biogas production was the input from universities, both in terms of the benefits brought by the closer monitoring of the process, and in terms of the lab scale testing, which enabled risk-free trials of major and minor processing changes (Christiansen, Personal Communication, 2006). Aage Sig Christiansen recognises the part that university research projects can play in the monitoring of the LinkoGas (and other full scale) digesters. With anaerobic digestion systems, as with other systems ‘knowledge is power’, and the more you know about a process the more you can improve it. When asked if there were any lessons to be learnt, or if there was anything that would be done differently if the plant were to be redesigned, a few suggestions were made;

- A screen/grid should be added at the wastes reception stage. This would remove solid plastics, pieces of rope *etc*. that sometimes find their way into the waste stream. A considerable amount of time is spent every week taking pumps apart and cleaning them to remove these non-organics.

- The pumps mentioned above are often submerged, in the wastes reception/storage tanks. As these pumps are submerged, cleaning/maintaining them is not an easy task.

- The plant should ALWAYS be built bigger than required. There are always more organic wastes available, and it is easier to fill up to capacity than to expand.

- Universities should be brought on board at an early stage to monitor the full scale process as part of research projects. With anaerobic digesters 'knowledge is power', and the more data you have the more you know about your process and the more you can 'tweak' things here and there to optimise performance.

- Along the same theme, having 'partner universities' to perform lab scale trials and experiments is very beneficial, as you can't experiment at full scale. There are plenty of minor amendments a manager may want to try, and lab-scale processes are necessary.

It was also mentioned that people building new plants still make the mistake of not 'learning from experience' and not taking on board advice from experienced operators. As an experienced operator, Mr Christiansen and other Danish biogas plant managers are regularly asked for advice or comments on the design of new plants. Often well intentioned advice is ignored, for the sake of short term cost-savings. Examples of this advice having been ignored were given. When asked if the plant would consider accepting BMW, the response was;

'*Why*?*.... There are plenty of other organic wastes to choose from'*.

The opinion was that it was not worth the risk, as any contamination on a plant of this scale could lead to massive digestate disposal problems and costs. Another barrier would have been the introduction of upfront mechanical separation processes, which are simply not necessary when liquid industrial and agricultural wastes are treated.

The LinkoGas anaerobic digestion system at Lintrup is a proven, successful operation that provides a solution to the slurry storage and disposal problems faced by the farmers, and also provides them with an extra income, from the gate fees received for organic industrial wastes and from energy sales. The simplicity of the plant, combined with the large volumes of organic waste available locally make it an attractive model. No definitive comment can be made on the plant economics, but considering the scale of the plant, its simplicity and the proximity of the waste producers, it is assumed that the business model is attractive. If the plant were to be rebuilt now, significant improvements could be made in a number of areas. As it stands, the plant must be considered durable, robust, and proven to be successful, although sedimentation may prove a problem at some stage in the future.

REFERENCES

Christiansen A.S. (Plant Manager, Linkogas Biogas Plant, Lintrup, Denmark), Personal Communication, 2006.

LinkoGas Promotional Information, 2006.