Ludlow (Greenfinch) Trial Scale Kitchen Waste Treatment Plant

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CASE STUDY – SOURCE SEGREGATED BIOWASTES

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INTRODUCTION

The South Shropshire Biowaste Digester at Ludlow is intended to be a large-pilot scale digester, the first of its kind in the UK. Its design and construction was overseen by Greenfinch (www.greenfinch.co.uk), using Greenfinch technology, and was funded by the DEFRA New Technology Demonstration Programme and Advantage West Midlands. The plant is run by Greenfinch in partnership with South Shropshire District Council which own the site. The South Shropshire Biowaste Digester will receive 5,000 tpa of kitchen and garden waste from approximately 19,000 households throughout the South Shropshire District. The plant was started up in mid-March 2006, and was in an early stage of commissioning at the time of our visit (April 2006), working at around 25% capacity. An illustration of the aerial view of the plant is shown in Figure 1.

Figure 1 Illustration of aerial view of Ludlow Biowastes Treatment Plant (Greenfinch website, accessed April 2006)

WASTES COLLECTION

South Shropshire householders were supplied with a separate bin specifically for kitchen and green garden waste. Collection from the households is carried out fortnightly by Biffa on behalf of South Shropshire Council. Waste is delivered to the site 5 days per week at a rate of approximately 2 or 3 vehicles per day. Vehicles are weighed on a weighbridge entering and leaving the site. Initial experiences with the biowastes arriving at the Ludlow digester have shown that the quality of the source separation has not been as good as expected. The capture of food wastes has been significantly lower than expected (based on Greenfinch's pre-project research), and the garden waste stream is highly contaminated (Chesshire, Personal Communication, 2007). Up to April 2006 non-organic contaminants constituted up to 10% of the incoming waste stream (Chesshire, Personal Communication, 2006). While it could be expected that this will improve over time as the population adapts to the system, it is also clear that more public education/information is required to reduce the levels of contaminants. It is unclear what instructions South Shropshire residents have been given, but it is unlikely to have been given the same attention as in other European countries (see Salzburg, Vaasa and Västerås examples). The high incidence of contaminants is particularly detrimental at Ludlow (as opposed to other full-scale systems observed in Europe) as the plant at this initial stage has no mechanical separation stages to remove these contaminants. The plant was primarily designed to treat uncontaminated food wastes, rather than garden wastes.

PLANT DESCRIPTION

As mentioned above, biowaste is collected fortnightly and delivered to the site five days per week. The expected total solids content of the food waste is 15 – 25%. The plant, designed to treat around 5,000 tpa of biowaste, works in a simple flow-through procedure. First large and visible contaminants are manually removed. The waste is then pre-treated and stored in mixing tanks prior to its introduction to the digester. Biogas is produced, collected, upgraded and utilised for electricity and heat production. At the time of the visit the plant had not yet produced enough digestate to require disposal, but it is planned that it will be sent directly to local farmers for land application. In the near future a digestate treatment stage will be included in which the digestate will be de-watered and split into solid and liquid fractions, with both fractions intended for use on farmland. A process flow diagram of the Ludlow process is shown in Figure 2 and an artist's impression of the site is shown in Figure 3. The different parts of the process will be described below.

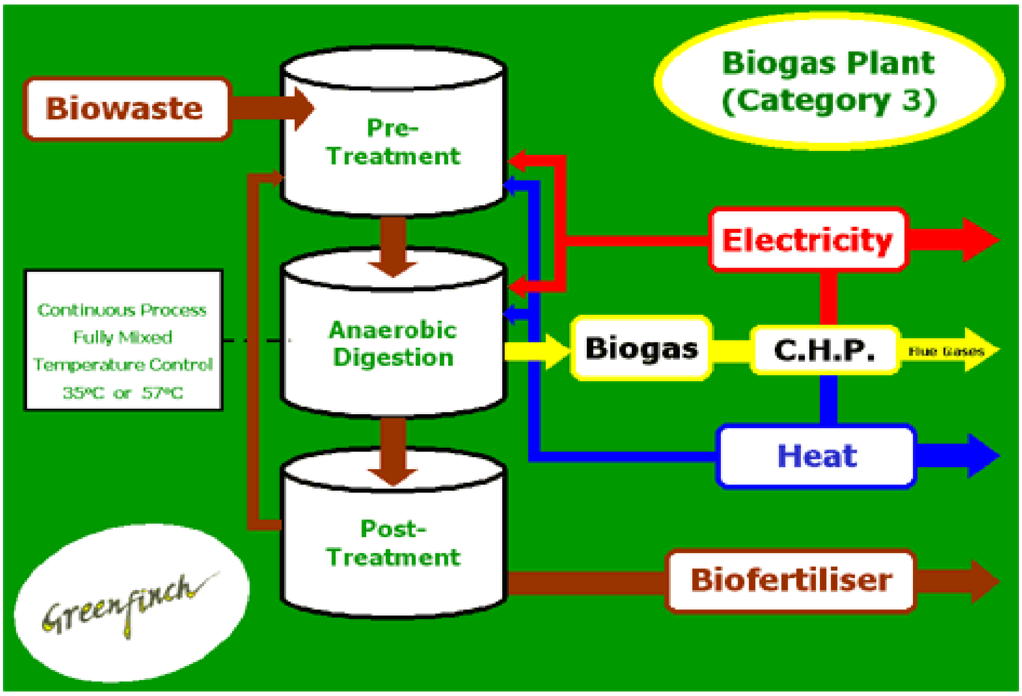

Figure 2 South Shropshire Biogas Plant process flow diagram (Greenfinch website, accessed July 2006)

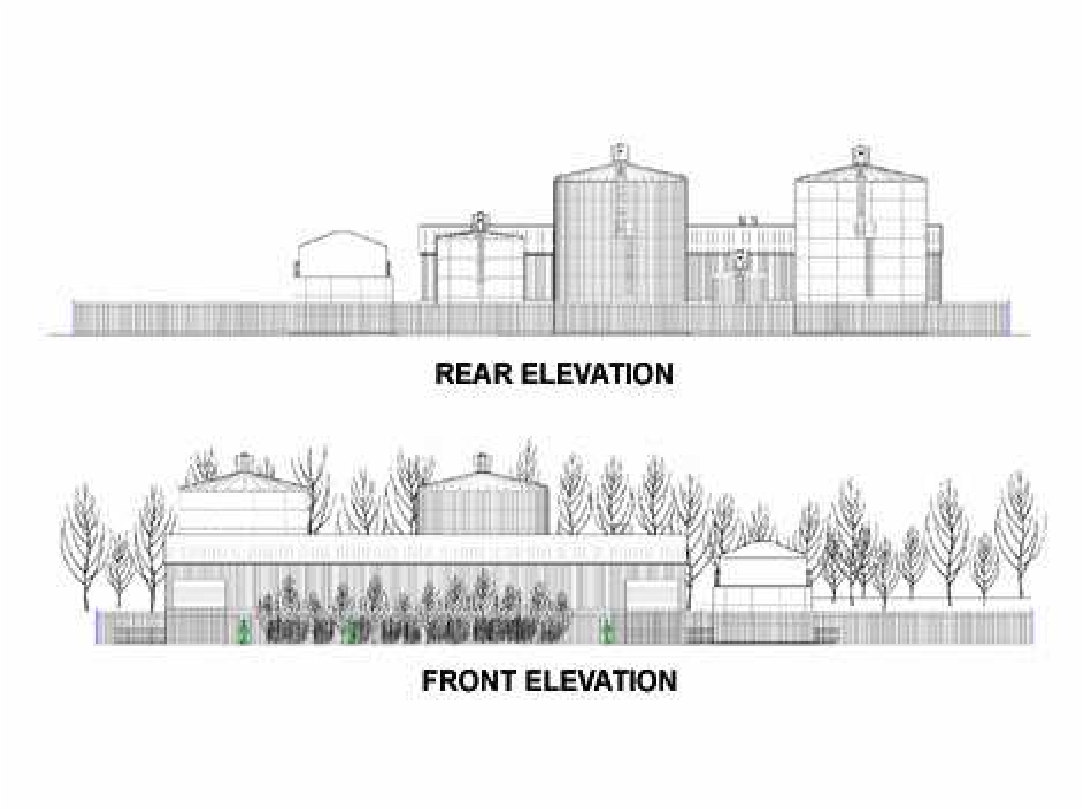

Figure 3 South Shropshire biogas plant, artists impression (Greenfinch website, accessed July 2006)

The front elevation in Figure 3 displays the building in which the waste is received, pre-treated and mixed, in which the visitor centre and offices are located and in which digestate will be treated in the future. Waste vehicles entering the site are weighed on a weighbridge in front of this building, and unload their waste through the door on the right. Digestate is removed through the door on the left. In the middle of the building there is a visitor centre on the top floor (under construction) from which both 'ends' of the process can be viewed, and offices on the bottom floor. From the rear elevation the actual layout differs from the illustration in that the biogas storage tank (here depicted to the left of the building) is actually located beside the pasteurisation stage. Aside from this, the process tanks can be observed (except for the mixing tank which is indoors) in the same order as the process flow occurs. From left to right (as in the flow of the process) these are the storage tank, the digester, the pasteurisation stage and the post-digestion storage tank.

PRE-TREATMENT

After weighing (Figure 4), the waste is delivered to an enclosed waste reception building (Figure 5) where air emissions are controlled by a biofilter. Waste is unloaded on to the floor where large and visible contaminants are manually removed.

Figure 4 Weighbridge and entrance to waste reception area

The waste is moved to the shredder by a 'bobcat' (mini-digger, see Figure 5). The incoming waste is shredded to a particle size less than 12 mm, and mixed with re-circulated digestate at a ratio of 1.5 – 2.5 : 1. The incoming waste and re-circulated digestate are mixed in a mixing tank which is also indoors (Figure 5). The digestate is added to adjust the solids content of the incoming waste stream from 15 – 25% (in the incoming waste) to the desired solids content of the waste stream entering the digestion system (12% TS). Approximately 88% of the TS is VS. The irregular waste inflow pattern is homogenised by the mixing and storage tanks, and digester feeding is as constant as possible in terms of volume and content.

When the waste is homogenised, and the desired TS levels achieved, the waste stream is pumped from the mixing tank to a storage tank, from which the anaerobic digestion system is continuously fed. The volume of the storage tank is sufficient to deal with a three day period with no incoming waste, so that the digestion system can run continuously through a bank holiday weekend with no deliveries of waste, and no topping up from the mixing tank.

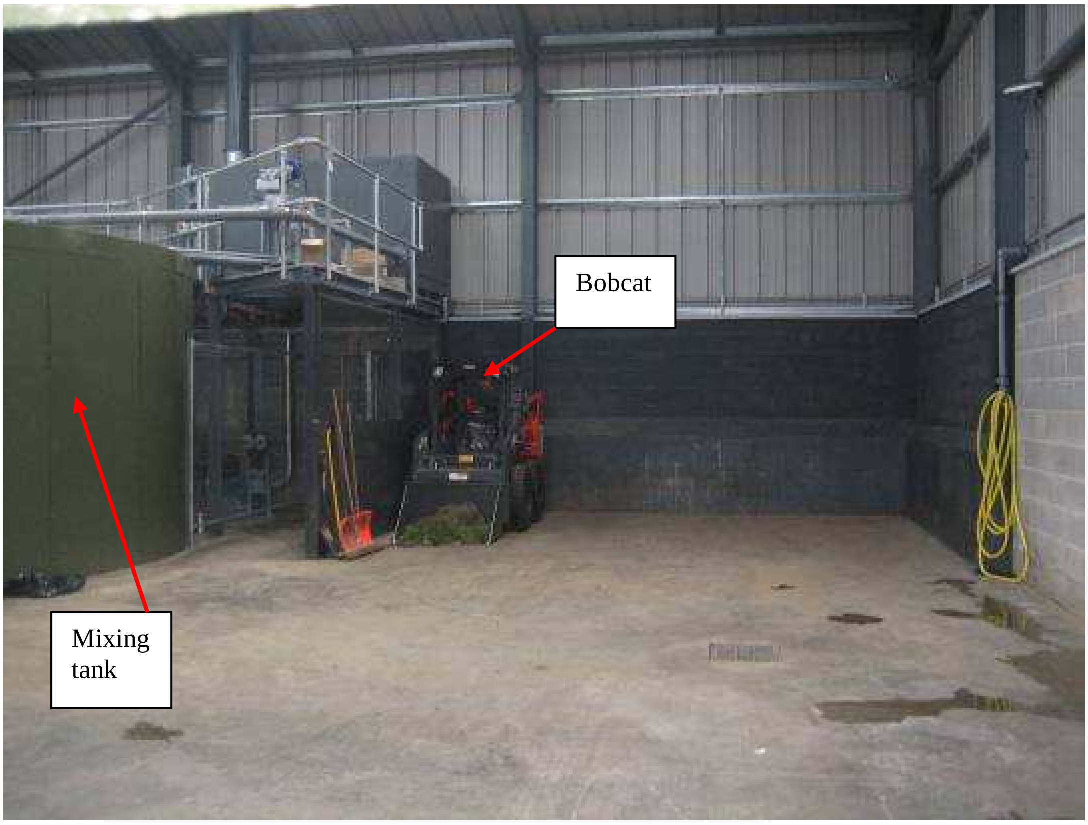

Figure 5 Wastes reception area (mixing tank and 'Bobcat')

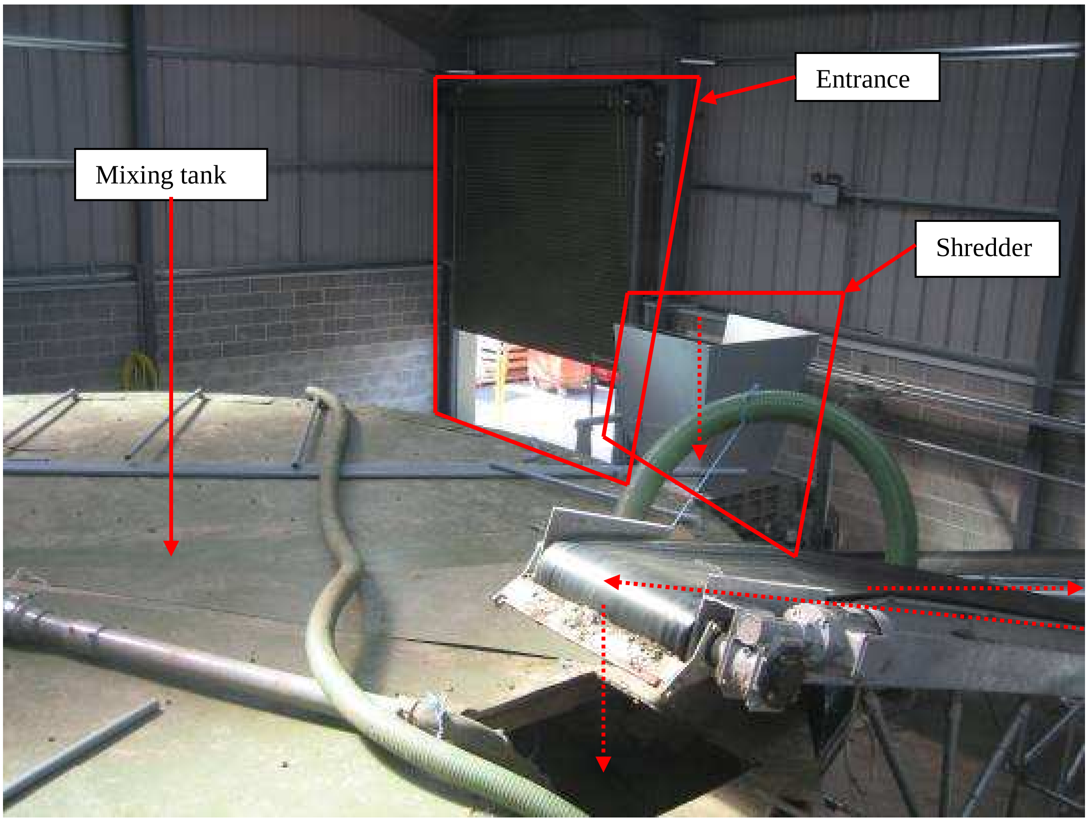

Figure 6 Mixing tank (shredder and waste reception area entrance)

ANAEROBIC DIGESTION

The anaerobic digester is a CSTR reactor, with a volume of 900 m^3, and retention time is 25 days. The digester is operated in the mesophilic temperature range (40°C), with heating carried out within the digester. Maximum particle size in the waste stream entering the digester is 12 mm, and the total solids content is 12%. The digester is intermittently fed at intervals of 1 hour. The pH is in the range of 7.3 – 7.5. Gas production, gas content and temperature will be measured on-line. At present there is no regular off-line monitoring, but Southampton University will be monitoring the following parameters; % TS, % VS and pH, alkalinity and VFAs (by titration). Pasteurisation currently occurs after the digestion step, although the process is engineered such that pasteurisation can occur either before or after digestion. It is intended to trial both options and document which option produced more favourable results. During the pasteurisation stage the waste stream is heated to 72°C for a period of four hours. The digestate will be tested monthly for pathogen content.

DIGESTATE

After digestion, the digestate, now with a total solids content of 7%, will be stored in a digestate storage tank (volume 900 m^3) prior to being de-watered and taken off site. At the time of the visit the post digestion treatment system had not yet been added. Digestate at present is simply stored (at 7% TS) before its application to farmland. A digestate treatment, which involves pressing to produce a solid digestate and liquid fertiliser is planned for the near future. Once this is operational, the two pasteurised products, soil-improving fibre and liquid fertiliser, will be available to local farmers. It is anticipated by Greenfinch that the digestate will be of sufficient quality to be applied to agricultural land, and that local farmers will be very keen to accept it due to the increasing price of mineral fertilisers. In the future, the liquid fraction of the digestate can be re-circulated and added to the incoming waste stream rather than digestate, as occurs presently. This liquid fraction will be easier to pump. The digestate storage tank is identical to the digestion tank, in order to facilitate an anticipated scale-up in the future.

WATER AND WASTEWATER TREATMENT

No freshwater addition is required, but wastewater from the plant building (process washdown water *etc*.) and office buildings (bathroom and kitchen effluents *etc*.) are added to the system. These additions amount to approximately 200 m^3/a (Chesshire, Personal Communication, 2006). It is planned to spread the solid and liquid fractions of the digestate to farmland, so no wastewater treatment will be necessary.

BIOGAS UTILISATION

As the plant is not yet operating at full capacity and is still in start-up, no biogas production data is available. However 100 – 140 m^3 of biogas per tonne of waste input is anticipated, increasing towards the top end as the percentage of kitchen waste in the incoming waste stream increases. A CHP engine unit is used to harness the energy from the biogas. Both heat and electricity are produced, a proportion of which are used for on-site heat (30%) and power (5%) requirements. In the future, once steady operation is established proven, excess heat and power can be used by local businesses on the industrial business park.

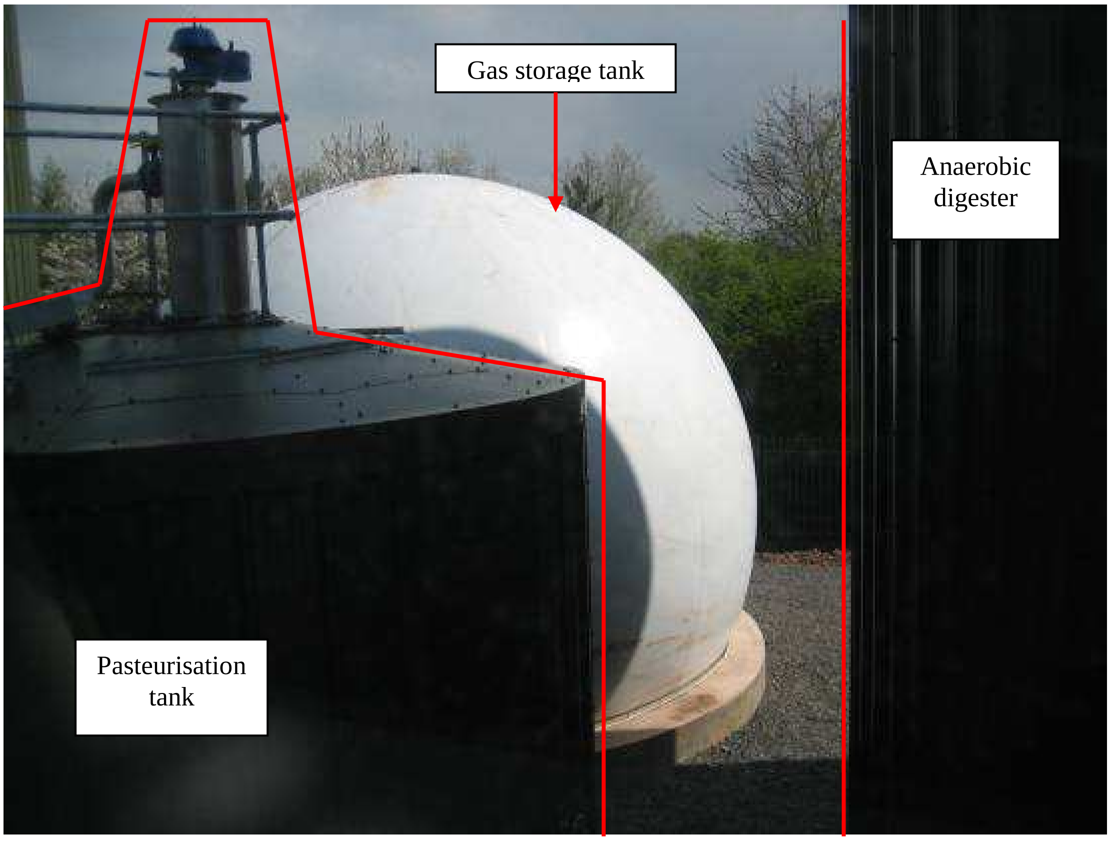

Figure 7 Pasteurisation tank (with gas storage tank in background and digester on the right)

ENERGY PRODUCTION

Once up and running at the designed capacity, the plant is expected to produce 100 – 140 m^3 of biogas per tonne of waste input. If this biogas production is realised, the plant could expect to produce 901 – 1,261 MWh/a of electricity (based on a methane percentage of 60% and an electrical conversion efficiency of 30%). It is expected that 5% of the electricity produced will be used on site (Chesshire, 2006), therefore exportable electricity should be in the region of 856 – 1,198 MWh/a. Excess heat energy will also be produced.

EXHAUST GAS TREATMENT

Exhaust gases from the wastes reception area, and from the biogas engines are treated by a biofilter to reduce odour emissions. The biofilter is made from locally available material, in this case a heather-based medium.

MASS BALANCE

An important feature of food waste is its moisture content; household kitchen waste includes 770 kg of water for every tonne of waste and this water must be accounted for in the mass balance (Figure 8). The biogas plant transforms 74% of the dry matter into biogas, leaving a digestate with a dry matter content of only 7%, which becomes liquid fertiliser. The figures for the CHP unit assume stoichiometric combustion, although there will inevitably be excess air. The difference between the gross and net energy figures is the amount used by the process. On-site requirements include electricity to drive the shredders, pumps and mixers, and heat for the pasteurisation and digestion processes. Greenfinch is currently working to establish the actual energy and mass balances.

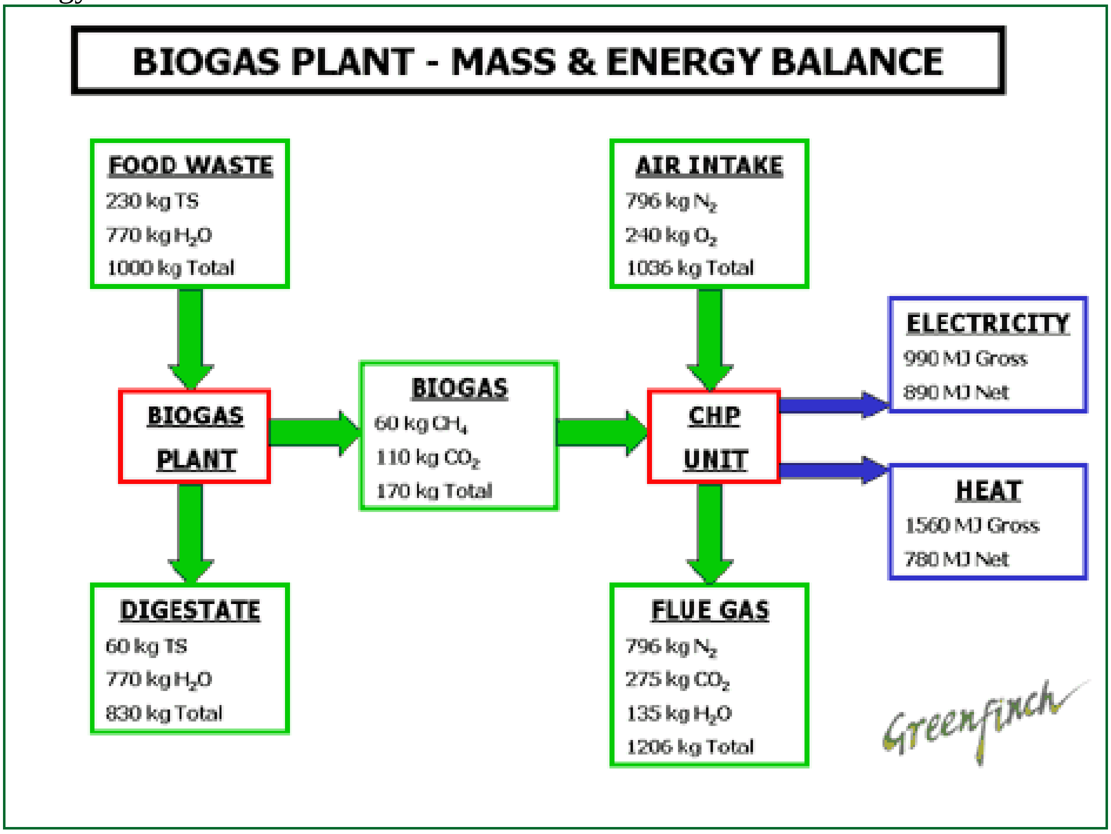

Figure 8 Mass balance (Greenfinch website, accessed April 2006)

VISUAL AND LOCAL IMPACT

The siting of the plant was ideal, being in an industrial estate close to the population who supplied the waste, and close to the fields on which the digestate will be spread. The site had good road access and minimal visual impact. The site is next door to a Biffa Depot and a car repair garage. The wastes reception area is enclosed, and all subsequent wet digestion is enclosed within pipes and tanks. The digestate treatment and loading area (although not yet completed) will also be also indoors. As such, there was no smell at all, even in the reception hall. Housekeeping was exceptional, although the plant was new and there had been no deliveries in a few days. Little noise was generated by the plant. There was more noise from the nearby road. A few weeks after start up the garage next door asked 'When are you starting up?' (Chesshire, Personal Communication, 2006).

COSTS AND ECONOMICS

The scale of the plant limits the potential of achieving positive plant economics. The cost per tonne of waste treated will be much greater than that for a larger plant. It is highly likely that plants at this scale would struggle to be competitive, although this plant was intended to be a trial to assess technical feasibility rather that to provide economic operation. An income of £20 from electricity sales per tonne of food waste (rather than food and garden waste) is expected. This will be achievable providing:

i. On-site electricity use does not increase.
ii. Biogas production is consistently over 130 m^3/tonne of waste treated, and
iii. The price of electricity from biomass remains over £80/MWh.

No cost data was provided but will be made fully available as part of a DEFRA review, currently in progress. At a CIWM Conference in Perth, Scotland in March 2006, Greenfinch presented the South Shropshire Biowaste Digester Project, and in the presentation, made reference to an economic model based on the same system at a scale of 20,000 tpa of source separated kitchen waste. The table presented is replicated here in Table 1.

Table 1 Economic model for a similar system treating 20,000 tpa (Chesshire, 2006)

Income	Gate fee (£45/t)	900,000	
	Electricity (£22.50/t)	450,000	
	Heat (£10/t *possible but not included*)	0	
	Biofertilser (£5/t *possible but not included*)	0	**1,350,000**
Expenditure	Staff	250,000	
	Maintenance	150,000	
	Biofertiliser Transport	100,000	
	Other Costs	100,000	**600,000**
Annual surplus			**750,000**
Capital costs			**3,500,000**

A scale of 15,000 - 20,000 tpa is generally regarded as the minimum scale at which the AD of biowastes is economic. A possible exception to this is the modular Kompogas system which appears to run economically at a smaller scale (in Switzerland). At approximately 20,000 tpa the incomes derived from gate fees and electricity export can start to exceed the project realisation costs, which can be significant irrespective of the scale of the plant. It was stated that the model 'erred on the side of caution', and that electricity prices should increase in the future. Also, although with an appropriately sited plant it should be possible to generate an income for the heat energy, no income from heat has been included in this model. With the biofertiliser it is wise to assume no market value, despite the increasing fertiliser prices and trend towards organic consumption, and assume that transport costs will need to be met. Any income from biofertiliser can be considered a bonus. This model assumes that the biofertilser will meet all of the necessary quality targets for land application. In case it does not, there will be another significant disposal cost to be factored in. Of course, as in many cases around Europe, were the plant to win contracts to treat organic industrial wastes, then the gate fees and income from biogas production would be further increased.

CHALLENGES AND DISCUSSION

As the Ludlow plant is a demonstration facility rather than a full scale plant, it can not be compared with other processes that have been implemented at full scale. Technically, the success of the plant will become apparent with time. However the degree of contaminants in the source separated biowaste will need to be reduced, alternatively a more substantial mechanical separation stage may need to be retro-fitted before the biological treatment stage. Lessons can be learnt from other European systems regarding the public education and 'incentives' for citizens to source separate. It is unrealistic to expect citizens to 'instantly' provide a source separated biowaste suitable for AD with no mechanical separation stages. The citizens of Västerås (Sweden) source separated their kitchen waste for 5 years prior to an anaerobic digestion system being set up. This gave the local government and the digestion company ample chance to take action to reduce the levels of contaminants and improve the quality of the incoming biowastes. This is particularly important at Ludlow given the present lack of mechanical separation facilities.

A visitor centre is planned and was under construction during our visit. The visitor centre will offer good views of the unloading/pre-treatment and mixing areas, and the digestate treatment areas (both of which are also in the building). It is also possible to view the storage, pasteurisation and digestion tanks. It is expected that the plant will be visited primarily by other local authorities, and also by schools and universities. A teaching/lecture room will also be available. As previously mentioned, visitor centres and public education represent very important components of any wastes management strategy, and the inclusion of a visitor centre in the plant design is a very positive step.

In the Greenfinch system re-circulated digestate is added to adjust the solids content of the incoming waste stream. The more digestate that is re-circulated, the less efficient the process will be, as the digestate will take up a considerable volume passing through the system again (despite being already treated). If this volume was not re-circulated, extra capacity would be available to treat more waste at a plant with the same volumes. Also, energy will need to be expended re-heating, re-pasteurising and re-pumping material that has already been treated. Despite these disadvantages re-circulation (or recycling) is often used in anaerobic digesters and is beneficial in terms of reducing fresh water requirements, inoculating the incoming feed with bacteria, recycling heat from the digester and mixing within the digester.

All of the waste sent to the site can in theory be diverted from landfill. The exact percentage diverted depends on the proportion of contaminants in the incoming waste. Landfill diversion is also dependent on the digestate reaching a sufficient standard to be spread on agricultural land. As yet there is no separation of inert contaminants other than crude manual separation, and the presence of visible contaminants in the digestate may prove harmful to its desirability for agricultural applications.

One of Greenfinch's interim conclusions from the project was that their technology was more appropriate for food waste than for food and garden waste. However, considering the plant accepts food and garden waste, improvements could potentially be made by:

- Public education and incentives to reduce contaminants in their source separation bins.
- At 10% contaminant levels, extensive manual separation will be required or the shredder could wear out quickly.
- The retro-fitting of some form of mechanical separation techniques. On larger scale plants these mechanical separation techniques would be included in the design (Chesshire, Personal Communication, 2007).
- Paper (or biodegradable plastic) bags could be used for biowastes collection (as in Sweden and Denmark).
- Coarse inert contaminants (sand, stones, glass, ceramics) are not removed from the waste stream and could damage pumps and piping throughout the system. A sand separator/de-gritter could be added.
- Fine inerts could accumulate in the digesters, gradually taking up more space and causing blockages. If these inerts are not removed before digestion, the digester should perhaps contain some mechanism by which these inerts could be removed.
- After the de-watering stage is operational, the recycling of process water will be more effective than recycling digestate.
- Transport of de-watered digestate to farmland may be cheaper than transport of digestate with its present higher water content, although the solid and liquid fractions of the digestate will both be sent to farms.
- The building of solid and liquid digestate storage facilities at the farms to which the digestate will be sent. This would allow farmers to accumulate the products, and apply them at the times of peak plant growth for maximum impact. Perhaps these storage facilities are already a part of the system, or are planned, but no mention was made of them.

All of the above suggestions would increase the costs of the project. This project is a trial scale project, and as such the plant is not ideally suited to achieve significant financial benefit from gate fees and energy production revenues. The Ludlow facility must be regarded (especially by decision makers) for what it is: A trial scale process, from which lessons will be learned, and solutions to problems found.

To summarise, it is felt that the Ludlow plant may experience operational difficulties as a result of the unforeseen levels of inorganic contaminants contained in the incoming waste stream. The installation of a mechanical pre-treatment stage, including a sand separator, will increase capital costs considerably but provide more stable operation and reduce on-going operational costs. The economics of the plant would also be greatly improved at full scale, perhaps with other organic wastes being co-digested. It is unclear how sand and other inert inorganics will be removed from the digester. The sedimentation of these fine inerts may prove problematic if no removal mechanism has been included in the digester design.

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