SLR

**Green Cone Sustainability Appraisal**

**Final Report**

green cone

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solutions for today's environment

**CONTENTS**

## 1.0 BACKGROUND TO THE PROJECT

Greencone is an at-home composting system which offers an alternative means of disposing of organic kitchen waste to Anaerobic Digestion (AD) and In-Vessel Composting (IVC). Green Cone does not have the same requirements for the collection and transportation of waste from the household and the construction and maintenance of large treatment plants compared to large AD and IVC systems, and so potentially it offers financial and environmental benefits over these systems.

The scope of this report is to outline these differences in terms of carbon emissions, other major environmental aspects, and the difference in financial costs.

The sustainability appraisal considers the environmental and economic impacts associated with the collection, transportation and processing of 10,000 tonnes of organic kitchen waste within a typical Shire Council (in this case Cheshire) on the basis of all food waste being delivered to a new centralised waste handling facility.

## 2.0 DESCRIPTION OF THE SYSTEMS

### 2.1 Introduction

Two alternative technologies have been considered; in-vessel composting and anaerobic digestion.

### 2.2 In-vessel Composting

Composting is a biological process in which micro-organisms convert biodegradable organic matter into a stabilised residue known as compost. The process uses oxygen drawn from the air and produces carbon dioxide and water vapour as by-products.

The term ‘in-vessel composting’ (IVC) is used to cover a wide range of composting systems all of which feature the enclosed composting of waste, therefore allowing a higher degree of process control than is possible with windrow composting.

In-vessel systems can be broadly categorised into five types: containers, silos, agitated bays, tunnels and enclosed halls.

The analysis considers three different in-vessel composting systems:

- an enclosed hall windrow composting system with an automatic compost turning machine system by LINDE;
- an in-vessel vertical flow system by TEG; and
- an in-vessel batch vessel with enclosed windrow system by Vital Earth.

Further descriptions of each of these systems are provided in Appendix A.

### 2.3 Anaerobic Digestion

Anaerobic digestion (AD) is the biological degradation of organic material in the absence of air. The process provides volume and mass reduction and delivers valuable renewable energy with biogas production. Anaerobic digestion is particularly suited to wet, organic material and as such has been used for the treatment of sewage sludge for over a century. It is also suitable for treatment of the organic portion of municipal waste and in particular kitchen and food derived material.

Anaerobic digestors come in a range of designs; this review has concentrated on two commercially available technologies from Linde and Dranco. Further descriptions are provided in Appendix A.

## 3.0 SUSTAINABILITY APPRAISAL METHODOLOGY

### 3.1 Scope of the Sustainability Appraisal

The methodology employed for the sustainability appraisal evaluates the performance of the two technology types against a number of sustainability criteria, covering environmental, planning and economic considerations, as follows:

- Carbon emissions associated with the facility including indirect, direct and avoided burdens. A combination of the software WRATE and recent technical data has been used;

- Carbon emissions associated with waste collection and transport;

- Costs including lifecycle capital and operating costs for the IVC or AD facility, costs of transportation based on recent project specific data and typical costs associated with procurement, site identification and planning;

- Other major environmental aspects limited to emissions of acid gases, local air pollution and emissions to water; and

- Planning and site identification issues. The approach to this has been to assign typical timescales to each of these aspects of project delivery and then credit Green Cone with the tonnage of waste capable of being diverted within that same period.

### 3.2 Environmental Assessment

The environmental assessment methodology considers the major environmental criteria including global warming, acid gas emissions, local air pollution and emissions to water.

Environmental impacts for each of the systems are calculated on a life cycle basis; that is, the methodology considers the net effect of a range of direct, indirect and avoided burdens, as follows:

| | | |
|---|---|---|
| Direct Process Burdens | • Direct process burdens | Direct burdens from plant operation (e.g. direct emissions from the process) and construction |
| | • Energy Input | Direct burdens associated with energy use (e.g. diesel for mobile machinery) |
| | • Operational waste outputs | Direct burdens associated with landfilling of waste products from the process |
| Indirect Burdens | • Construction material inputs | Indirect burdens associated with manufacture and provision of construction materials |
| | • Maintenance material | Indirect burdens associated with provision of maintenance materials |

| | | |
|---|---|---|
| | • Energy input | Indirect burdens associated with provision and consumption of electrical energy to operate the plant |
| | • Operational material input | Indirect burdens associated with provision of consumables to operate the plant |
| | • Operational water inputs | Indirect burdens associated with provision of water to the plant |
| Avoided Burdens | • Energy output | Avoided burdens associated with displacement of electrical energy generation from conventional fuels |
| | • Operational product output | Avoided burdens associated with use of the waste derived compost and subsequent displacement of conventional compost products, such as peat derived compost |

In addition to the aforementioned burdens the analysis also considers burdens associated with the collection and subsequent transportation of collected food waste. Cheshire has been taken as a representative semi-rural area for the model to allow calculation of average transportation distances for collecting waste and transferring it to a central waste facility.

### 3.3 Transport and Landfill Impacts

The following assumptions have been taken in order to calculate the carbon emissions associated with transportation:

- The 10,000 tonnes of waste is collected over a one year period from Cheshire, which has a land area of 2,083 $km^2$ (Government statistics online). The food waste arisings in Cheshire are assumed to be 3.08 kg per household per week (assuming a participation rate of 80%; a capture rate of 89% and the proportion of household waste in food is 17%) and all of the waste is taken to one disposal facility. There is a distance of 5km from the start / end of the collection round to the depot.

- The waste is collected using Terberg's ABUV food collector with a capacity of 3.5 tonnes and a utilisation rate of 80%. The fuel consumption of the vehicle is 0.83 litres per mile when full; 0.53 litres per mile when empty; and 69.05 litres per 100km during collection (WRATE). The calorific value of diesel is 10.8 kWh per litre and the fuel emission factor is 0.25 kg $CO_2$ per kWh (Carbon Trust).

The average timescale for project delivery of an AD/IVC plant is 18 months; during this time waste will still be taken to landfill and as a consequence give rise to emissions of carbon gasses. The modelling assumes that landfilling of 100 kg of food waste will produce 45 kg $CO_2$ eqv[1] (the York report). This data includes a 70% capture rate from the local landfill site (the UK average at the time of publication in 2002) as well as transfer to the landfill site and landfill machinery.

[1] The Material Flow Analysis and Ecological Footprint of York, Stockholm Environment Institute, York, August 2002

### 3.4 Carbon Offsets

Of particular importance when looking at waste management systems, especially those that derive energy from the waste, are the 'carbon offsets' associated with displaced energy generation and compost production.

Standard LCA practice is to credit any energy exported by the waste plant with a carbon benefit associated with the displacement of the marginal energy generation mix[2]. As such, each unit (kWh) of waste derived energy is assumed, on average, to displace 523 grams of fossil fuel derived carbon dioxide, based on the marginal UK electrical energy mix.

This assumption of displaced carbon clearly benefits energy based waste technologies. However, for a number of reasons the assumption that waste derived energy displaces conventional electrical energy may not be relevant for small scale anaerobic digestion, for the following reasons:

- The main concern, especially with small scale generation, relates to the potential adverse impact on the electrical distribution network. The location of renewable resources and the likely plant capacities imply that small scale waste to energy schemes will generally be connected to distribution networks. Distribution networks were not designed to accept the power injections from these distributed generation (DG) sources and their connection creates a wide range of technical problems including bi-directional power flow, voltage rise and increased fault levels amongst others. Whilst these problems can be mitigated against the associated financial cost may be prohibitive[3];

- Despite UK plans/goals to derive more electrical energy from renewable resources, any renewable generation brought on line now is more likely to satisfy year on year increasing energy demand rather than displacing existing generation capacity; and

- Anaerobic digestion is only one of a number of renewable energy technologies that could be invested in to meet renewable energy targets. Where other technologies show environmental, economic or planning benefits they may be developed in preference to anaerobic digestion.

Given the above considerations, the assessment includes a sensitivity analysis which considers the impact of different carbon offset assumptions. The sensitivity analysis is limited to carbon impacts but is equally relevant to other environmental impacts.

It should be noted that this sensitivity analysis lies outside conventional LCA thinking, although this should not detract from its relevance for this particular analysis

### 3.5 Environmental Impact Categories

Aside from global warming (carbon emissions), the environmental analysis considers four other environmental criteria:

- Abiotic Resource Depletion measured as tonnes of antimony (Sb) equivalent (T Sb eq.);

[2] Assumed to be a combination of fossil fuel (coal, oil natural gas), nuclear and renewables

[3] Maximising Renewable Energy Integration within Electrical Networks. http://www.see.ed.ac.uk/~gph/publications/WREC2005_DG.pdf

- Human Toxicity measured as tonnes of 1-4 Dichlorobenzene equivalent (T 1,4-DCB eq.);
- Acidification ; and
- Eutrophication measured as tonnes phosphate equivalent (T PO4- eq)

The methods used for determining each of these environmental impacts is set out below.

#### *3.5.1 Abiotic Resource Depletion*

This impact category indicator is related to the extraction of scarce minerals and fossil fuels. The Abiotic Depletion Factor (ADF) is determined for each type of mineral and fossil fuel based on the remaining reserves and rate of extraction. It is based on using the equation, Production/(Ultimate Reserve)$^2$ and comparing this to the result for Antimony (Sb), which is used as the reference case. The reference unit for abiotic depletion is therefore kg Sb equivalent.

#### *3.5.2 Human Toxicity*

The emission of some substances can have impacts on human health. Characterisation factors, expressed as Human Toxicity Potentials (HTP), are calculated using the USES-LCA, multi-media fate, exposure and effects model.  For each toxic substance HTPs are expressed using the reference unit, kg 1,4 dichlorobenzene (1,4-DCB) equivalents.

#### *3.5.3 Acidification*

Acidic gases such as sulphur dioxide ($SO_2$) react with water in the atmosphere to form “acid rain”, which can cause ecosystem impairment. Acidification Potential (AP) is expressed using the reference unit, kg $SO_2$ equivalent. The Acidification Potential is a measure of the disposition of a unit of the mass of a component i to release H+ protons, expressed in terms of the H+ potential of the reference substance $SO_2$

The method only accounts for acidification caused by $SO_2$ and NOx.

#### *3.5.4 Eutrophication*

Nitrates and phosphates are essential for life but increased concentrations in water can encourage excessive growth of algae, reducing the oxygen within the water and damaging ecosystems. Eutrophication potential is based on the work of Heijungs (1992), and is expressed using the reference unit, kg $PO_4$ equivalents.

### 3.6 Economics

The methodology also includes a cost comparison; the costs associated with the centralised food waste treatment facility have been calculated incorporating the following cost elements:

- Gate fee for treatment of food waste at a suitable facility;
- Leasing cost for vehicles;
- Fuel for vehicles;
- Costs associated with procurement of the treatment facility (including planning, permitting and design); and
- Costs associated with landfilling of waste during the procurement phase.

# 4.0 RESULTS OF MODELLING

## 4.1 The Major Environmental Impacts of the Facilities

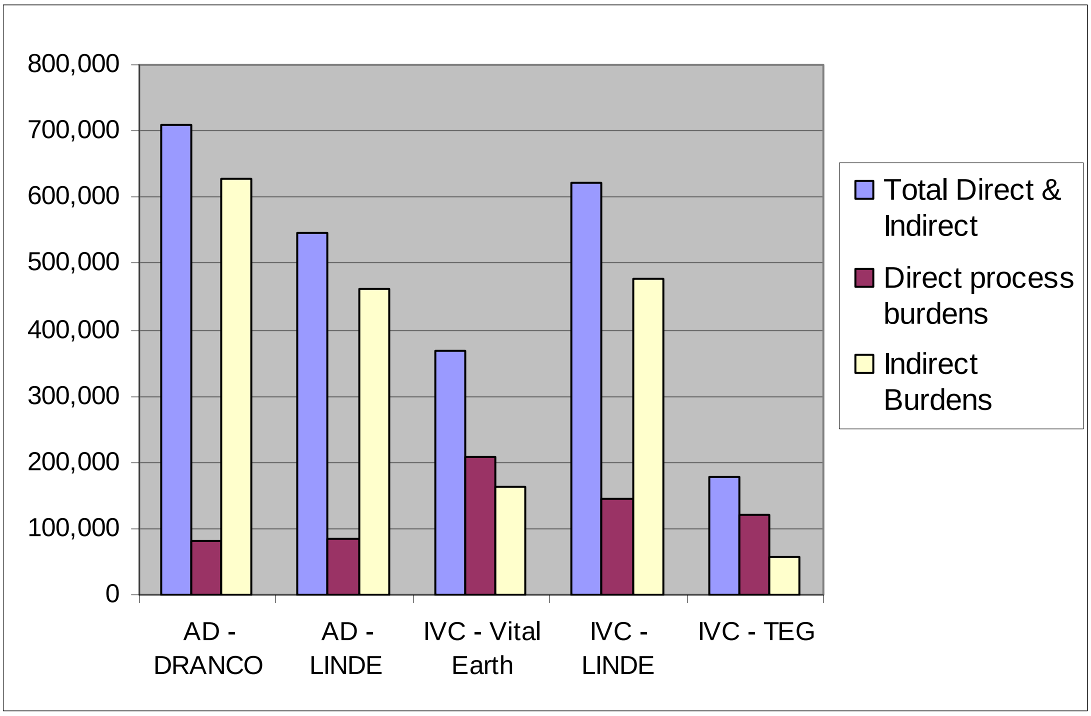
### *4.1.1 Introduction*

Set out below are the results of the carbon analysis for the waste handling facilities. The figures do not include the impacts associated with transportation and for landfilling of waste while the treatment process is being constructed and commissioned. These additional carbon burdens are discussed at a later point in this document.

### *4.1.2 Global Warming Potential*

Direct and indirect emissions are depicted in Figure 4/1, whilst Figure 4/2 presents the avoided burdens associated with the generation of energy and production / utilisation of compost products.

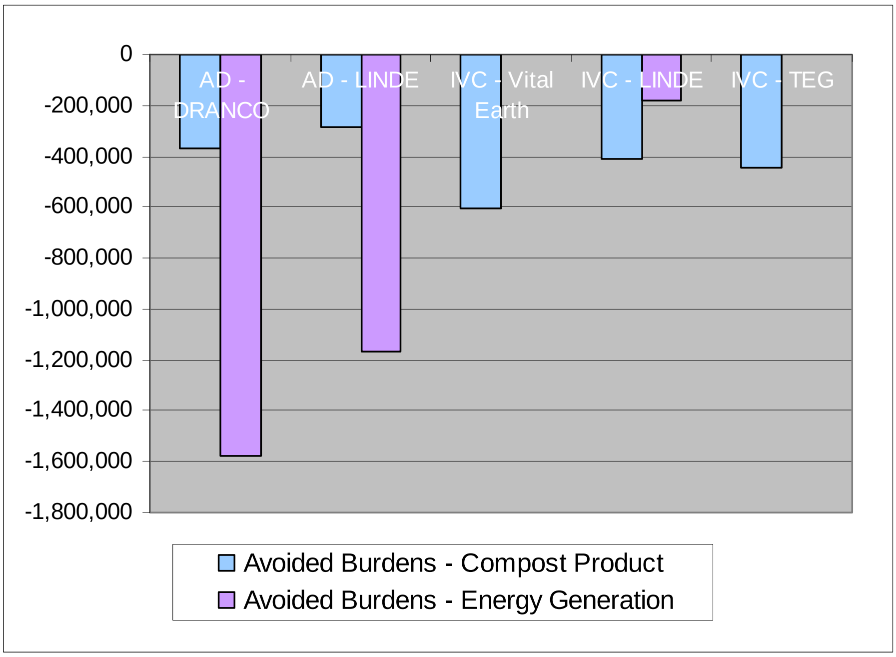
**Figure 4/1: Direct and Indirect Carbon Emissions (kg $CO_2$ eqv) for Treatment of 10,000 tonnes of Food Waste**




Indirect burdens for the AD systems are generally higher than for IVC systems due mainly to the higher energy consumption associated with operating the plant. However, the Linde system also exhibits high energy burdens due to the reliance on mechanical turning and forced aeration which are both absent from the other two IVC processes.

Direct process burdens for the IVC facilities are higher than those for AD facilities, which is generally related to the greater energy input in the form of diesel fuel for mobile equipment.

**Figure 4/2: Avoided Burdens (kg $CO_2$ eqv) for Treatment of 10,000 tonnes of Food Waste**




Avoided burdens are made up of two components - displacement of conventional energy generation and displacement of conventional compost products.

The AD facilities exhibit substantially greater avoided burdens than the IVC facilities, due in the main to the generation of electricity and displacement of conventional electrical energy. The Linde system also claims to recover energy from the composting material that may be used in low grade heating applications.

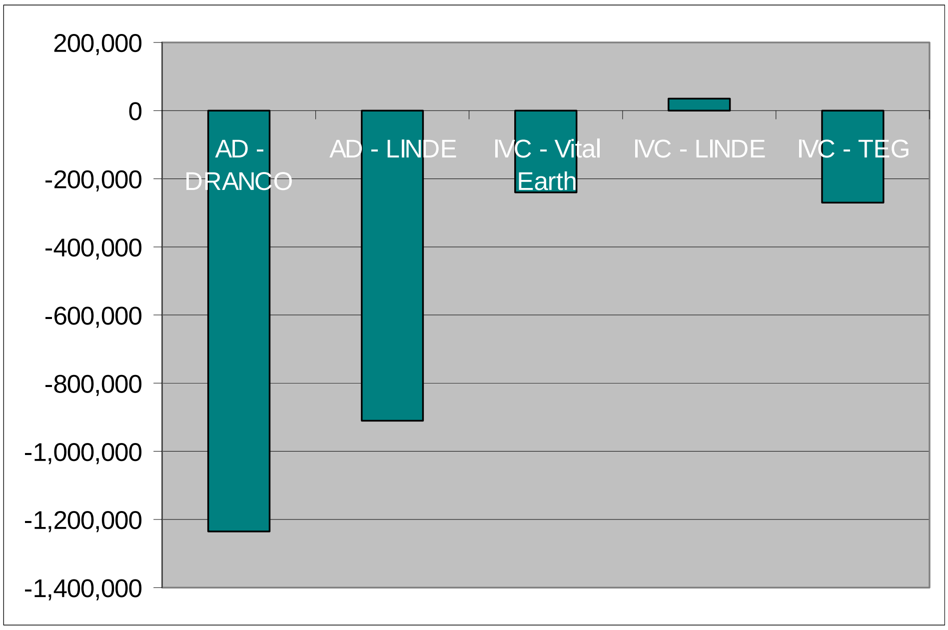
Avoided burdens for the compost product vary across the different processes for two main reasons. Firstly, the quantity of compost derived from a given mass of input material varies because of the different processing regimes and degree of processing inherent in each process. Secondly, but less importantly, is that each process assumes a different offset compost product, either PAS100 compost, APEX compost or AD cake and within WRATE (LCA modelling software) these are assigned different offset benefits.

Total carbon burdens (process only), calculated as the sum of direct, indirect and avoided burdens are presented in Figure 4/3.

The avoided burdens of anaerobic digestion are an order of magnitude greater than the direct and indirect burdens; as such Figure 4/3 indicates that anaerobic digestion facilities result in a substantially lower total carbon burden than IVC facilities.

The significance of the avoided burden is almost entirely due to the displacement of carbon intensive electricity generation.

**Figure 4/3: Total Carbon Burdens (kg $CO_2$ eqv) for Treatment of 10,000 tonnes of Food Waste**




## 4.2 Sensitivity Analysis – Avoided Energy Burden

The analysis so far is based on the displacement of conventional electrical energy. For the reasons discussed in Section 3.4 a sensitivity analysis has been included that considers the impact on the carbon footprint of displacing other renewable technologies rather than conventional energy generation.

The analysis has been limited to those technologies of similar size and scale to anaerobic digestion and that could be potentially integrated within a community heat and power scheme. The comparator technologies that have been chosen for this analysis are thus biomass (miscanthus, high density wood chip), photo-voltaics, and wind. The assumed carbon impacts of each of the technologies are presented in Table 4/1 with further discussion on the derivation of the figures presented in the subsequent paragraphs.

**Table 4/1: Carbon Impacts of Renewable Energy Technologies[4]**

| Comparator Technologies | g CO2/kWh |
|---|---|
| Biomass (Miscanthus) | 93 |
| High Density Wood Chip | 25 |
| Photo-voltaics | 58 |
| Wind | 4.64 |

[4] POSTNOTE. October 2006. Number 268. Carbon Footprint of Electricity Generation

**Table 4/2: Carbon Impacts of Renewable Energy Technologies Compared to Anaerobic Digestion**

| Comparator Technologies | g CO2/kWh | Compared to Linde gCO2/kWh | Compared to Dranco gCO2/kWh |
|---|---|---|---|
| Biomass (Miscanthus) | 93 | 526.65 | 262.91 |
| High Density Wood Chip | 25 | 594.65 | 330.91 |
| Photo-voltaics | 58 | 561.65 | 297.91 |
| Wind | 4.64 | 615.01 | 351.27 |
| **Average** | | **574.49** | **310.75** |

Table 4/2 indicates the carbon impact of anaerobic digestion when other renewable energy technologies are replaced. Since AD are high net carbon emitters in comparison, the displacement of other renewable energy technologies results in positive carbon emissions associated with AD.

**Miscanthus and High Density Wood Chip(Biomass)**

Biomass is obtained from organic matter, either directly from dedicated energy crops like short-rotation coppice willow and grasses such as straw and miscanthus, or indirectly from industrial and agricultural by-products such as wood-chips. The use of biomass is generally classed as 'carbon neutral' because the $CO_2$ released by burning is equivalent to the $CO_2$ absorbed by the plants during their growth. However, other life cycle energy inputs affect this 'carbon neutral' balance, for example emissions arise from fertilizer production, harvesting, drying and transportation. Biomass fuels are much lower in energy and density than fossil fuels. This means that large quantities of biomass must be grown and harvested to produce enough feedstock for combustion in a power station. Transporting large amounts of feedstock also increases life cycle $CO_2$ emissions.

The range of carbon footprints for biomass is related to the type of organic matter and the way it is burned. Combustion of low density miscanthus results in higher life cycle emissions (93g$CO_2$eq/kWh), than gasification of higher density wood-chip (25g$CO_2$eq/kWh).

**Photo-voltaics**

Photo-voltaics (PV), also known as solar cells, are made of crystalline silicon, a semi-conducting material which converts sunlight into electricity. The silicon required for PV modules is extracted from quartz sand at high temperatures. This is the most energy intensive phase of PV module production, accounting for 60% of the total energy requirement.

Life cycle $CO_2$ emissions for UK photovoltaic power systems are currently 58g$CO_2$eq/kWh, although this is expected to fall in the future, with improvements in the design and construction of PVs.

**Wind**

Electricity generated from wind energy has one of the lowest carbon footprints. As with other low carbon technologies, nearly all the emissions occur during the manufacturing and construction phases, arising from the production of steel for the tower, concrete for the foundations and epoxy/fibreglass for the rotor blades.

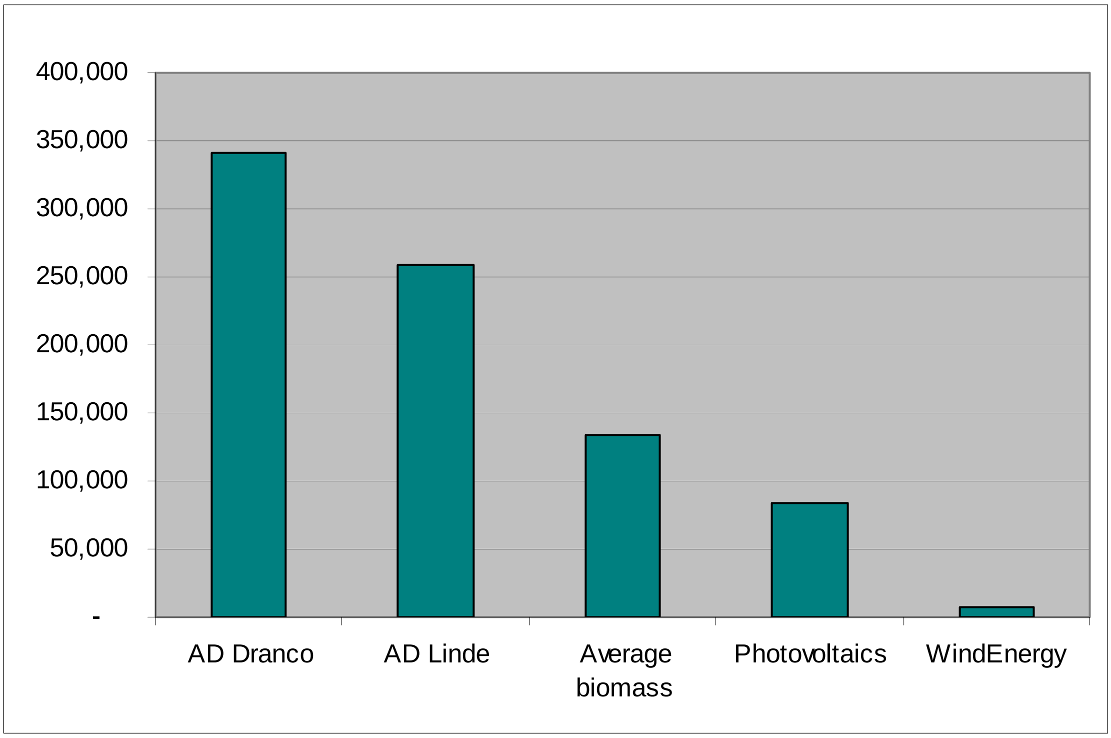
These account for 98% of the total life cycle $CO_2$ emissions. Emissions generated during operation of wind turbines arise from routine maintenance inspection trips, including use of lubricants and transport.

Figure 4/4 shows how total burdens change when the aforementioned renewable technologies (biomass, wind, solar PV) are considered as the offset energy. Since renewable technologies exhibit a low carbon footprint (Table 4/1), the avoided burdens associated with displacement of carbon intensive energy are not replicated with renewables and consequently anaerobic digestion results in a positive rather than negative (avoided) carbon burden when compared to other renewable technologies.

As a consequence, where AD replaces another alternative renewable technology, there are no avoided burdens to consider and therefore the carbon footprint of AD will be greater than the renewable energy technology that it is replacing.

In reality the argument is perhaps only fully relevant for biomass as this technology is likely to be the only viable competing technology for a large scale urban development[5] particularly where a requirement for both heat and electrical power exists.

**Figure 4/4: Total Carbon Burdens (excluding Avoided Energy) for AD Compared to Alternative Renewable Energy Technologies (kg $CO_2$ eqv)**




The analysis clearly indicates that the carbon impact of anaerobic digestion is directly dependent on the energy type that is assumed to be displaced; where displacement of conventional energy generation is assumed then AD results in a significant avoided burden,

[5] In certain circumstances, wind generation may also be relevant

however where a conventional renewable technology is displaced the carbon footprint is positive i.e. results in an overall increase in carbon emissions.

### *4.2.1 Carbon Emissions of Waste Transportation and Landfilling Prior to Project Commencement*

A typical timescale of 18 months has been assigned to the project delivery of an average AD or IVC plant. On the basis of treating 10,000 tonnes per year, the amount of waste treated over this timescale for project delivery has been calculated, and then divided by the average lifespan of the five AD/IVC plants modelled. This gives the amount of waste that would have to be disposed of due to the project delivery timescale on an average yearly basis for the lifespan of the plant, as 750 tonnes.

For the purpose of this report all of this 750 tonnes of waste is considered to have gone to landfill. The carbon emissions that would be generated by landfilling this quantity of organic kitchen waste are then calculated.

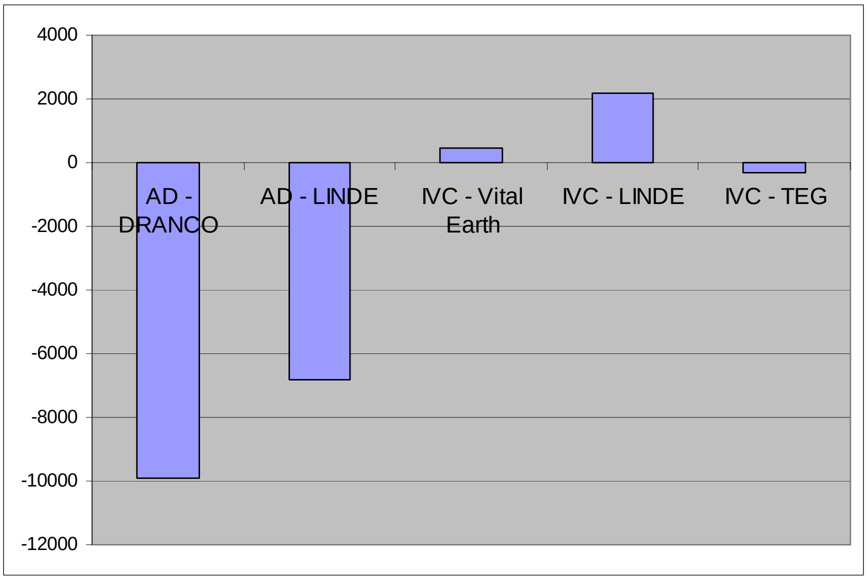
Carbon impacts of transportation are calculated by considering the average distance travelled between houses and the processing site and the resulting fuel consumption.

Carbon burdens associated with both of the above activities are considered identical for each of the treatment processes.

### *4.2.2 Abiotic Resource Depletion*

Figure 4/5 depicts abiotic resource depletion for each of the technologies. Both of the AD technologies exhibit negative (avoided) burdens which is almost exclusively associated with the avoidance of coal and natural gas extraction for conventional electricity generation.

**Figure 4/5: Abiotic Resource Depletion**

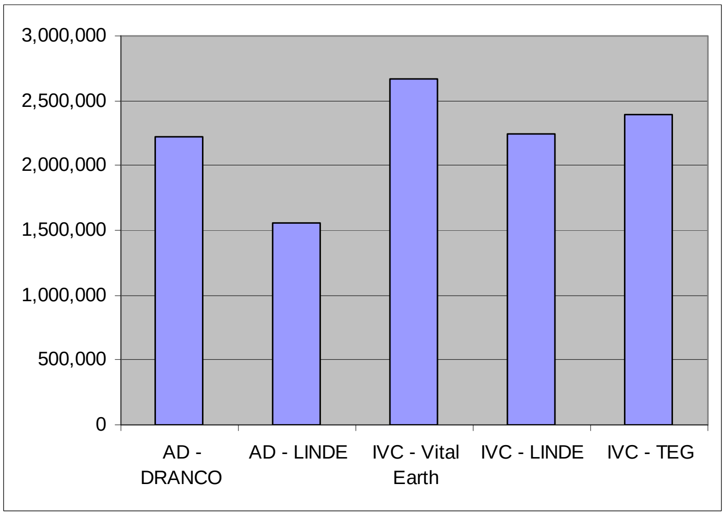



As with global warming these figures would not be as significant if the displaced energy was derived from an alternative renewable energy technology.

### *4.2.3 Human Toxicity*

All technologies exhibit a positive human toxicity burden associated mainly with direct process burdens and in particular emissions of chromium, lead and nickel to soil. The source of these emissions is not clear from the analysis but could be related to diesel usage on site or contamination of the waste source.

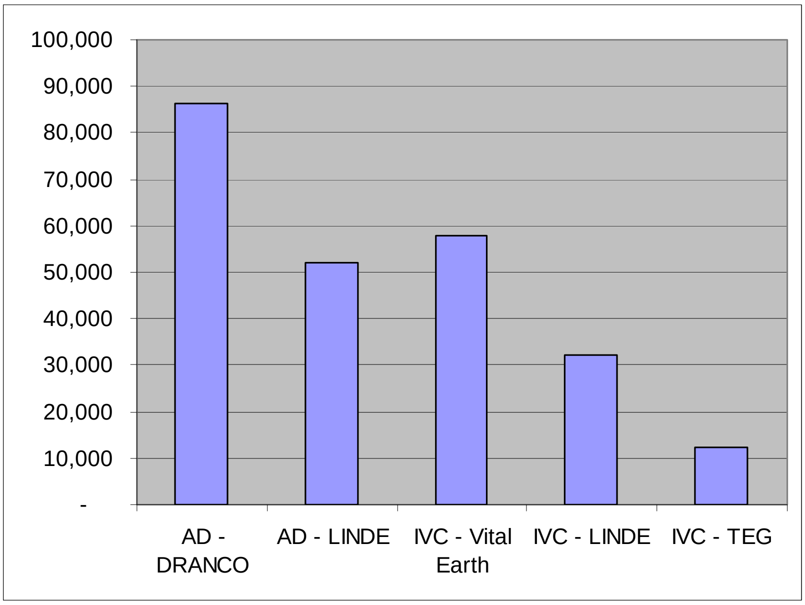
**Figure 4/6: Human Toxicity**




### *4.2.4 Acidification*

All technologies show a positive acidification burden (Figure 4/5); in the case of AD this is associated with direct process burdens from the combustion of fuel on site.

**Figure 4/7: Acidification**

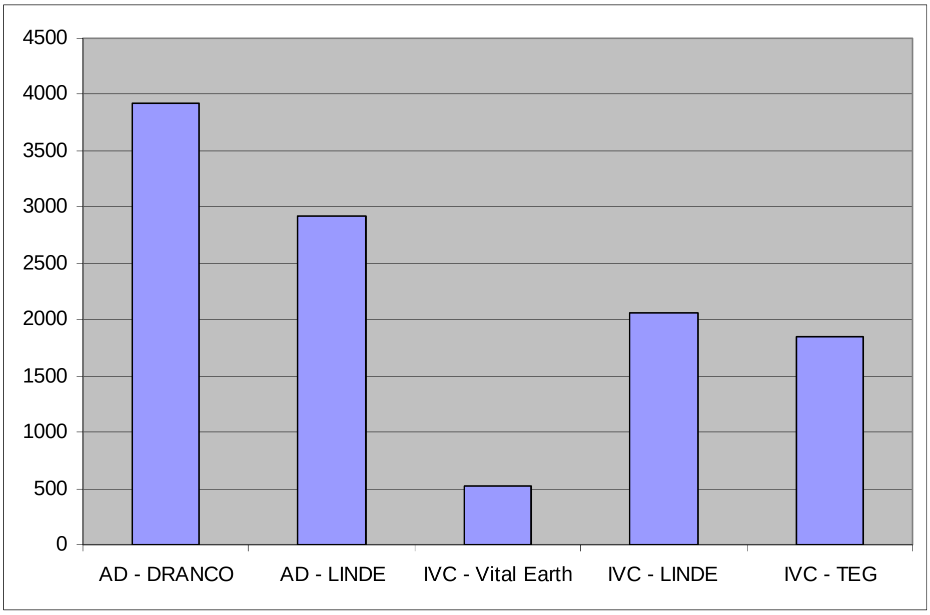



The high figure exhibited by Vital Earth is associated with construction materials and more particularly steel manufacture. The AD facilities also include a slight avoided burden associated with the displacement of NOx and SOx from fossil fuelled power stations.

### *4.2.5 Eutrophication*

All processes exhibit a positive eutrophication burden associated with direct process burdens and in particular the release of ammonia and other nitrogen gases to air and water as a consequence of the biological degradation of the waste.

**Figure 4/8: Eutrophication**




## 4.3 Economic Costs

The costs associated with a centralised food waste treatment facility have been calculated incorporating the following cost elements;

- Gate fee for treatment of food waste at a suitable facility;
- Leasing and operational costs for vehicles;
- Fuel for vehicles;
- Costs associated with procurement of the treatment facility including site identification, planning, environmental impact assessment, design and procurement; and
- Costs associated with landfilling of waste during the procurement phase.

### *4.3.1 Assumptions*

The following assumptions have been made in order to calculate the costs:

- Gate fee for AD and IVC facility taken as £60 per tonne;
- Other project specific costs include site identification costs at £17,500; planning and environmental impact assessment (EIA) costs at £100,000 and procurement costs at £562,500;
- The cost of the fuel for collection is £0.90/litre;
- Other vehicle costs are taken as follows - annual cost per driver is £22,000 and per loader is £17,000; 12 months road tax costs £1000; 12 months insurance costs £750;

RCV annual servicing and maintenance costs £10,000; overheads cost 10% (Conwy 2005). The vehicles are leased at a cost of £800/month; and

- Each Green Cone diverts 0.5 kg of waste per day (which is an estimated amount generated by a family of four), costs £42.50 and has a warranty of 10 years (Green Cone)

### *4.3.2 Costs Associated with Centralised Waste Treatment (based on 10,000 tpa)*

Annual costs associated with centralised waste treatment are presented in Table 4/2; as a comparison the annual costs for food digesters are also presented.

**Table 4/2: Costs of Centralised Treatment and Food Digesters**

| Cost Element | Annual cost | Cost per tonne |
|---|---|---|
| Centralised Treatment Gate Fee | £600,000 | £60.00 |
| Vehicles incl. Overheads | £761,874 | £93.40 |
| Fuel | £172,176 | |
| Project Delivery | £34,000 | £3.40 |
| Landfilling prior to construction | £70,054 | £7.01 |
| **Total Annual Costs (Centralised Treatment)** | **£1,638,103** | **£163.81** |
| | | |
| **Food Digester Costs** | **£232,881** | **£23.29** |

A breakdown of the methodology and calculations used to derive the above costs is presented in Appendix B.

## 5.0 COMPARISON OF CENTRALISED TREATMENT AND FOOD WASTE DIGESTERS

### 5.1 Global Warming and Economic Cost

To this point, the analysis has concentrated on determining the economic and environmental profile of different centralised food waste treatment technologies. Set out below, and drawn from graphs presented earlier, is a comparison of the absolute values with those derived for the food waste digesters.

**Table 5/1 Comparison of Global Warming Burdens (Conventional Energy Mix)**

| | Direct /Indirect Burdens kg $CO_2$e / t waste | Transport Burdens kg $CO_2$e/ t waste | Preconstruction Landfill kg $CO_2$e / t waste | **Sub-total excluding avoided energy kg $CO_2$e / t waste** |
|---|---|---|---|---|
| AD - DRANCO | 71.04 | 51.65 | 36.92 | **159.62** |
| AD - LINDE | 54.63 | 51.65 | 36.92 | **143.20** |
| IVC - Vital Earth | 36.85 | 51.65 | 36.92 | **125.43** |
| IVC - LINDE | 62.17 | 51.65 | 36.92 | **150.75** |
| IVC - TEG | 17.87 | 51.65 | 36.92 | **106.44** |
| Food Waste Digesters | 5.06 | 0 | 0 | **5.06** |

| | Avoided Burdens – based on current Energy Generation mix kg $CO_2$e/t waste | **Including Avoided Energy Burdens kg $CO_2$e/t waste** | Avoided compost burdens kg $CO_2$e/t waste | **Including avoided compost burdens kg $CO_2$e/t waste** |
|---|---|---|---|---|
| AD - DRANCO | -157.51 | **2.10** | -36.98 | **-34.88** |
| AD - LINDE | -116.94 | **26.27** | -28.73 | **-2.47** |
| IVC - Vital Earth | 0.00 | **125.43** | -60.79 | **64.64** |
| IVC - LINDE | -17.74 | **133.00** | -40.94 | **92.06** |
| IVC - TEG | 0.00 | **106.44** | -44.81 | **61.63** |
| Food Waste Digesters | 0.00 | **5.06** | 0 | **5.06** |

**Table 5/2 Comparison of Global Warming Burdens (Renewable Energy Mix)**

| | **Sub-total excluding avoided energy kg $CO_2$e / t waste** | Avoided Burdens Renewable Energy Generation[6] **kg $CO_2$e / t waste** | **Offset Renewable Energy kg $CO_2$e/t waste** |
|---|---|---|---|
| AD - DRANCO | **159.62** | 50.75 | **210.37** |
| AD - LINDE | **143.20** | 62.26 | **205.46** |
| IVC - Vital Earth | **125.43** | 0.00 | **125.43** |
| IVC - LINDE | **150.75** | -17.74 | **133.00** |

[6] Based on figures presented in Table 4/2 converted from g/kWh to kg CO2e/t. The displacement of other renewable energy technologies results in positive carbon impact for AD. The Linde offset energy is heat only which is unlikely to be supplied by other renewable sources.

| | | | |
|---|---|---|---|
| IVC - TEG | **106.44** | 0.00 | **106.44** |
| Food Waste Digesters | **5.06** | 0.00 | **5.06** |

Table 5/1 clearly shows that from a global warming perspective, food waste digesters result in a lower global warming burden than centralised treatment options. Even when the avoided burdens associated with energy generation are taken into consideration, food waste digesters perform as well, if not better, than centralised facilities.

It is only when the avoided burdens associated with the use of digestate on land are included that the global warming burden for both anaerobic digestion systems reduces below that of food waste digesters.

Where renewable energy rather than conventional energy is assumed to be the displaced energy type the global warming burdens for anaerobic digestion substantially exceed those for food waste digesters.

The costs of centralised treatment compared to food waste digesters are presented in Table 5/2 both as an annual cost and cost per tonne.

**Table 5/2 Comparison of Economic Costs**

| **Cost Element** | **Annual cost** | **Cost per tonne** |
|---|---|---|
| Total Annual Costs (Centralised Treatment) | £1,638,103 | £163.81 |
| Food Waste Digesters | £232,881 | £23.29 |

Food waste digesters are shown to be almost an order of magnitude cheaper than centralised treatment.

## 5.2 Other Environmental Factors

A range of other environmental burdens are presented and discussed in Chapter 4 which indicate that both AD and IVC facilities result in positive environmental burdens across all environmental factors (with the exception of anaerobic digestion and abiotic resource depletion).

Given the absence of a large processing facility food waste digesters are unlikely to yield the same level of environmental impact. Whilst the plastic used to manufacture the green cones may result in some environmental impacts this will be equivalent in magnitude to the environmental impacts associated with provision of kitchen caddys in the centralised model. As such it is reasonable to conclude that centralised food processing will perform worse than food waste digesters across a range of environmental factors.

## 6.0 CONCLUSIONS

This report seeks to establish the environmental impact and economic cost of centralised food waste processing compared to the use of domestic food waste digesters for the treatment of segregated food waste from domestic kitchens. The analysis compares the food waste digesters against a number of anaerobic digestion and in-vessel composting technologies.

In general across all economic and environmental factors centralised food waste treatment performs worse than food waste digesters with the difference more pronounced for in-vessel composting.

On this basis it is reasonable to conclude that as a means of treating domestic kitchen waste, food waste digesters offer environmental and economic advantages when compared to centralised food waste treatment facilities.

## 7.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Green Cone; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside.

## APPENDIX A – LARGE SCALE ANAEROBIC DIGESTION TECHNOLOGIES

### Process Outline

The DRANCO system in Antwerp, Belgium has a capacity of 50,000 tons of biowaste per year and has been operational since January 2000. It has a residence time of 42 days and a lifespan of 20 years.

**Pre-Treatment** – After the trucks have been weighed on the weighbridge, the biowaste is dumped on the tipping floor in the reception hall. The hall has a total surface of 380 m², corresponding with a storage capacity of approximately two days of normal supply. In the hall the waste is then either pushed aside by a shovel loader on a heap or pushed directly upon the walking floor. The pushing floor, existing of different moving frames, moves the waste automatically and equally to the pre-treatment. The tipping floor is slightly inclining so that the eventual percolate water runs to a pump well, where it is collected before it is pumped to the press water storage tank.

The incoming waste, falls on the inclining belt conveyor, which brings the waste to the feeding hopper of the first comminuting(pulverising) drum. The main purpose of the drums is to carry out a selective comminution of the waste: due to the turning of the drum the organic fraction is comminuted while the inert fractions remain unchanged. Paper and cardboard are, because of the humidifying, also partly comminuted. After an average retention time of 1.5 hours the waste is screened on 40 mm and the fraction smaller than 40 mm falls on the belt conveyor. To optimise the comminuting of the organic fraction, the fraction bigger then 40 mm is sent to the second drum via the belt conveyors. After a retention time of approximately 2 hours in the second drum, the waste is sieved again on 40 mm. The overflow after this second screening is brought via the belt conveyors alternately in one of the two waste containers. The pre-treatment must not be interrupted when one of the containers is full and brought to the landfill.

The fraction smaller than 40 mm after the second screening falls on the same belt conveyor as the throughput of the first sieve. The pulley of this belt conveyor is a magnet, which removes the ferrous metal out of the waste stream. This fraction is collected in the containers. The waste fraction smaller then 40 mm is then transported by conveyor to the dosing unit. The unit functions as a buffer between the pre-treatment and the anaerobic digestion part and ensures a continuous and steady supply to the digester.

**Anaerobic Digestion** - At the bottom of the pre-treatment section the waste falls into the hopper of the feed screw. This screw feeds and transports the waste further into the screw conveyor, which transports the material into the feeding pump. Above the feeding pump, a mixing unit is placed where the fresh organic fraction is mixed with the residue, coming from the digester and functioning as inoculum, with the purpose to start-up the anaerobic digestion as quickly and smoothly as possible. In the mixing unit a small amount of low-pressure steam is injected to heat up the mass to a temperature of 50-55°C. Subsequently the mass is pumped to the top of the digester where it is brought into the digester.

An intensive anaerobic digestion process takes place in the digester by dry solids content between 25 and 40% and a temperature between 50 and 55°C. The digester itself is a vertical cylindrical reactor with a conical outlet, made of steel and insulated to reduce heat losses. There is no mixing equipment inside the digester. The fermenting mass moves by gravity from top to bottom. The residue leaves the digester through the conical outlet and is partly recycled to the feeding pump by the extraction screws to serve as inoculum.

**Dewatering and Refining** - Through a second valve on the extraction screw, the residue is partly transported towards the press. To optimise dewatering, the residue is first intensively mixed with a polymer solution, prepared in the flocculant unit. The mixing is in batch mode: the residue and polymer solution are brought into the mixing unit, mixed and subsequently released into the hopper of the feeding screw, which feeds the mixture continuously to the press. The press water is collected under the press and pumped to the press water tank. To avoid settlement of sludge and sand, the tank is constantly stirred by a mixer.

The press water is subsequently sent by the pump to the centrifuge, where the sludge is removed. At the entrance of the centrifuge the press water can be flocculated with a polymer solution if necessary. The effluent of the centrifuge is collected in the pump well and sent to the water treatment unit. To counteract the forming of foam on the effluent, an anti-foam product can be added before and after the centrifuge.

The press cake is transported towards the vibrating sieve by means of the screw conveyors. The sieve conducts a separation on 10 mm. The fraction smaller than 10 mm falls on the underlying belt conveyor, which also transports the centrifuge cake and is brought by the conveyor belts and the screw conveyors to the aerobic post-composting hall. The overflow of the sieve is recycled by means of the belt conveyor and the screw conveyors towards the sieve to optimise efficiency of the sieving. Periodically the overflow will be discharged by belt conveyor to the container and afterwards sent to the landfill.

**Aerobic Post-Composting** - In the composting hall the fraction smaller then 10 mm is spread out in rows by an automatic dividing system and forms at the end a uniform heap approximately 2.3m high. The material, supplied by the screw conveyor, falls on a belt conveyor which can also move in 2 directions. A transportable chain conveyor with an open bottom is orthogonally positioned under the other belt, at one of the two ends. The material falls initially (when no compost row is converted) through to form a compost mound, as soon as the compost mound reaches a height of 2.5 m, the conveyor stretches the supplemental compost and forms a compost row. A probe is installed at the end of the row which detects when the compost row has reached its maximum length. In this way, a quasi-flat compost heap is created on the floor of the hall.

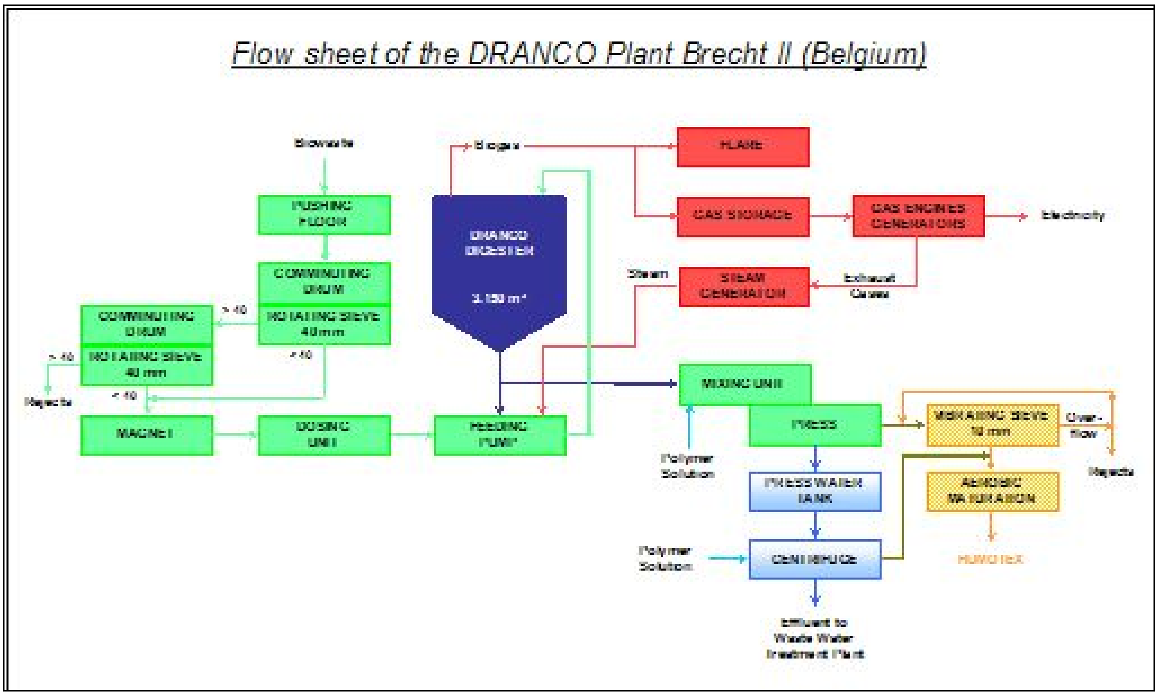
The fresh compost stays in the hall for an average period of 2-3 weeks during which it is intensively aerated. To achieve aeration of the compost air channels, covered by tiles, are provided in the bottom plate. A shovel loader removes the matured compost.

**Use of the Biogas** - During the fermentation phase approximately 60% of the volatile solids introduced into the digester are converted to biogas. The biogas collected in the digester flows under normal conditions, through difference in pressure, towards gas storage. The biogas flows through a filter, where larger impurities and the formed condensate water are removed. The condensate water is transported, by gravitation, to the water seal which functions as a buffer. Also at other places where biogas condensate water can be formed (e.g. in the biogas storage, by the flare, in the piping) the condensate water is collected and brought into this tank. The surplus in this tank runs over into the condensate water tank, from where it is pumped to the pump well of the effluent.

The biogas is sucked out of the gas storage and brought to a higher pressure by means of the blowers. Subsequently the biogas is burnt in the Combined Heat and Power units. In the CHP-units the biogas is primarily transformed into electricity for plant use and for sale. Secondly the lost heat is used in the steam generator to produce low pressure steam, which is injected in the mixing unit of the feeding pump. In case the gas consuming equipment is not functioning and the gas storage is filled or in case there is a surplus of biogas, the biogas can be burned off in ag flare. The CHP-units and the steam generator can also work on natural gas.

**Air Treatment** - To reduce the odours coming from the plant, and in some certain cases out of safety considerations, the installation is ventilated.  To minimise odour production, the different machines are, as far as possible, closed and locally ventilated.  The reception hall, the pre-treatment hall and the post-treatment hall are furthermore additionally ventilated.  The exhaust air in these halls is collected and used to aerate the compost in the post-treatment hall.  The hall is also ventilated to reduce odour emissions and to keep the working conditions in the hall acceptable.  In order to work in the hall, the aeration is turned off when somebody enters the room, while the ventilation goes on. The exhaust air of the equipment and the aerobic post-composting hall are brought together and humidified. This humidifying process is necessary to achieve good functioning of the biofilter. In the biofilter the odour components in the exhaust air are degraded by bacteria.  To increase the flexibility of the system, the biofilter is built of different compartments, so that the air flow through one compartment can be stopped in case of maintenance or need to replace the biofilter material in the compartment without interrupting the good operation of the total air treatment system.

**Flow Chart**



**Technology Picture**

**Anaerobic Digestion Large Scale Dry - LINDE**

**Process Outline**

The LINDE facility has a maximum capacity of 38,000 tons/year, a residence time of 42 days and an expected life span of 20 years

The incoming source segregated bio-waste is tipped into a bunker, which is equipped with an automatic pushing floor, which feeds the waste onto a conveyor belt. The conveyor transports the material to the treatment hall. The material is fed into a dosing unit, which can also be used in emergency situations as a feed hopper. Ferrous metals are separated from the bio-waste by means of an over band magnet before the waste falls into 2 parallel screw mills. In the screw mills the material is reduced to <120mm particle size.

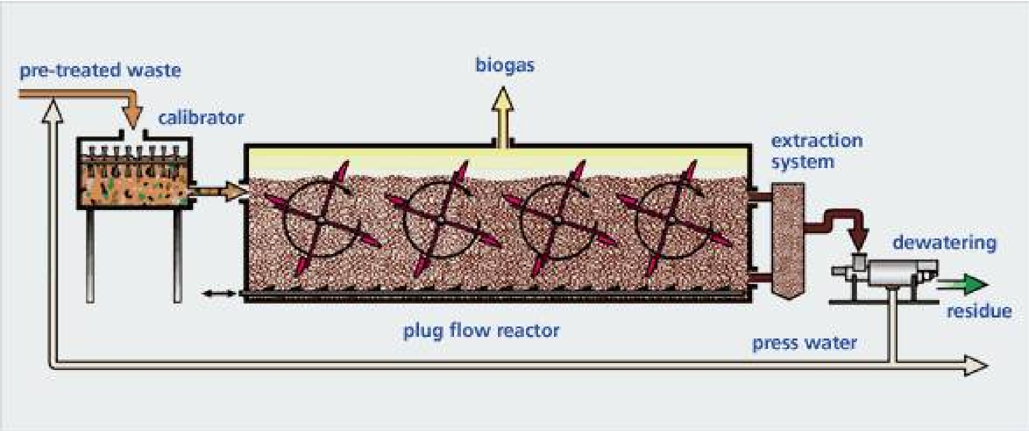
The material is fed into the pre-composting units by means of an automatic feeding system. In the pre-composting units the composting process commences and the material temperature reaches approximately 40-45°C. The residence time is approximately 2-3 days and the material is aerated. The pre-composting units are automatically unloaded and the 'hot' waste is transported to one of the 3 digesters. The digester-feeding unit includes a calibrator, to reduce the particle size to <40 mm, and a feeding spiral conveyor.

The retention time in the horizontal plug flow digester is 25 days. It is a thermophilic process working at approximately 57°C. The digested material is unloaded by means of a vacuum system into an intermediate buffer tank. From this tank the digestate is fed into one of two screw presses. The solid phase of the screw press is mixed with fresh green waste and this mixture is put into an intensive composting module for 14 days maturation. After 14 days the material is discharged automatically and is transported by means of belt conveyors into the post-maturation shed. According to the compost demand the material is stored or directly refined in a drum screen. Finally the compost is sold to private people or for agricultural use.

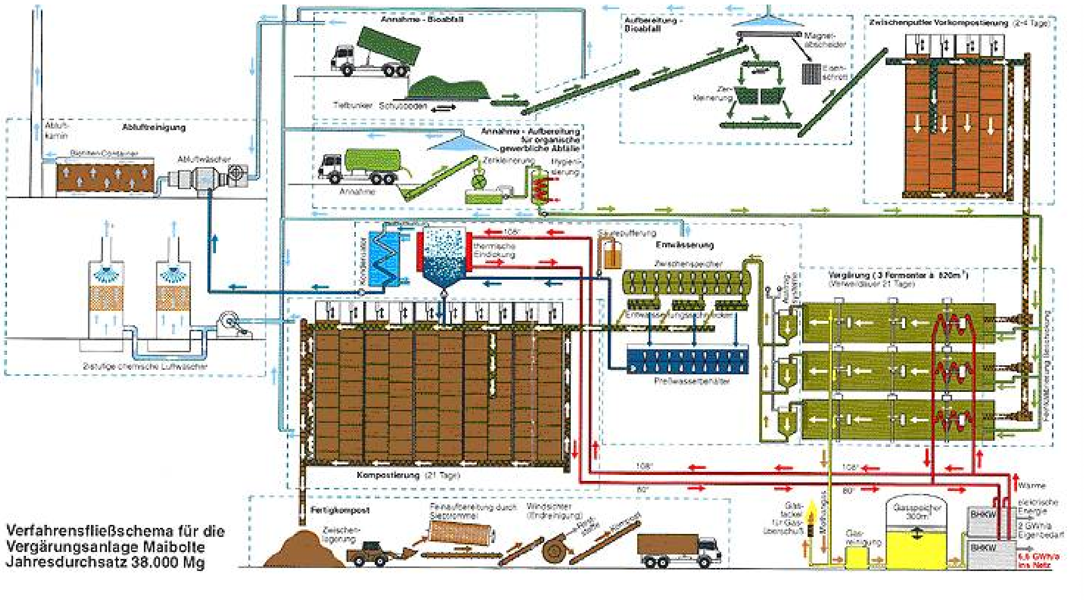
A proportion of the liquid from the dewatering unit is re-circulated into the digesters to inoculate the fresh mass and to adjust the total solids content. The excess liquids are pumped into an open tank and are taken away into the agriculture as liquid fertilizer.

The plant is equipped with a gas holder, a flare and a co-generation unit for energy recovery.

### Process Schematic




### Flow Chart




### Technology Picture

**Enclosed Windrow Composting with Automatic Compost Turning Machine - LINDE**

**Process Outline**

The Linde composting plant at Warngau, operated by Vivo, has a residence time of 70 days and a life span of 17 years. It accepts bio-waste and converts it into quality compost. Nothing is added to the process other than water. The composting plant is able to convert 16,500 tons of bio-waste a year and the entire process, including delivery, treatment and composting, take place in an enclosed stainless steel clad building which is 140 m long and 30 m wide

**The process consists of 6 stages:**

**Delivery** - The bio-waste is unloaded in a closed shed where a front end loader adds shredded garden waste as structure material. Ferrous metal is separated by an overband magnet and a drum-screen splits off the incoming material into a stream of <100 mm and >100mm. The smaller material is hand sorted and fed the compost process, whereas the larger material is fed to a Lescha screw-mill with a low speed to reduce the material size before being fed through the process again.

**Composting Process -** The composting process corresponds to the AE & E / Koch system in a moving-compost-clamp-procedure which can add 330 tons of biowaste at a time. From input to output each unit passes 9 fields. Input, turning-off and output are carried out automatically from an Automatic Compost Turning Machine with a separate stacker-bridge. The cycle of turning lasts 4-8 days, and the time to produce matured compost is 33-72 days. All important data is registered and documented in a computer. Levels of hygiene are guaranteed by temperatures of 75°C during the composting process.

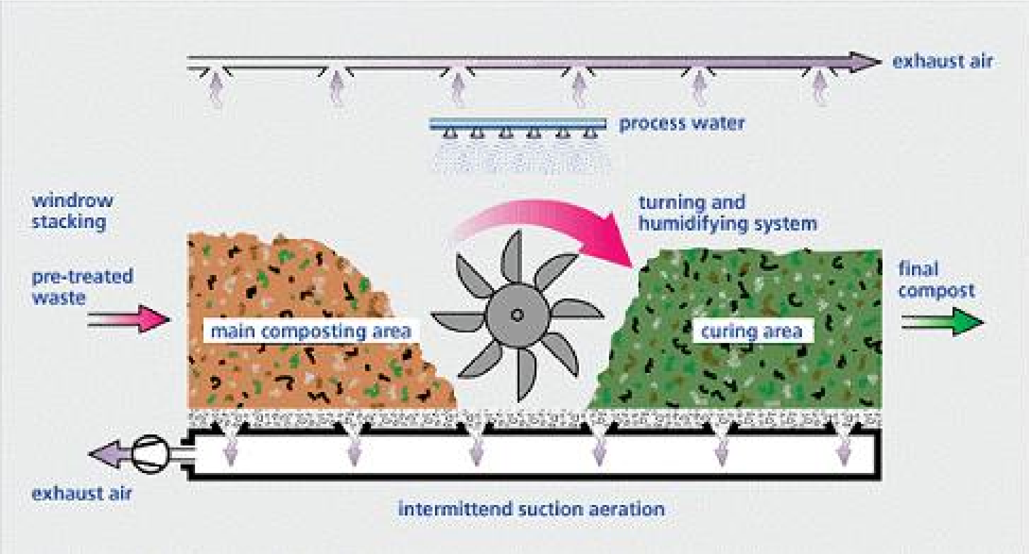
**Aeration Technology -** During the intensive composting process (composting fields 1-3) air is sucked through the windrows at a maximum rate of 10,000m³/hour. During the following composting process (composting fields 4-9) the aeration can switch from suck-aeration to pressure-aeration as required (at a maximum rate of 12,000m³/hour). The aeration process guarantees an oxygen-supply to the bacteria, which is important for the composting process. The delivery and composting shed is ventilated by 2 sucking aeration fans with a capacity of up to 30,000m³/hour each. This results in the composting shed maintaining a negative pressure. The extracted air is pre-cleaned with 2 air-washers and emitted via a bio-filter. This reduces odour emissions. Gas engines power the aeration fans and the excess heat from the composting process, aeration and the gas engines is fed to the industrial site's district heating system.

**Water Treatment -** Water emissions from bio-waste and composting fields, as well as condensate water from the aeration system, is collected in water basins and most of it is used again for the composting process. Only a small surplus of water is discharged to the urban sewage plant. Supplementary demand of water quantities is covered by a rainwater collection basin with a capacity of 90m³. This results in minimum water consumption and waste water generation.

**Composting Process -** Compost is processed using a starscreen (0-15mm) and a wind shifter, with stone separator, which removes plastic a metal foils, light materials and heavy solids (i.e. stones) from the screen oversize. The oversize material is stored and then fed into the process as a structure material when required.

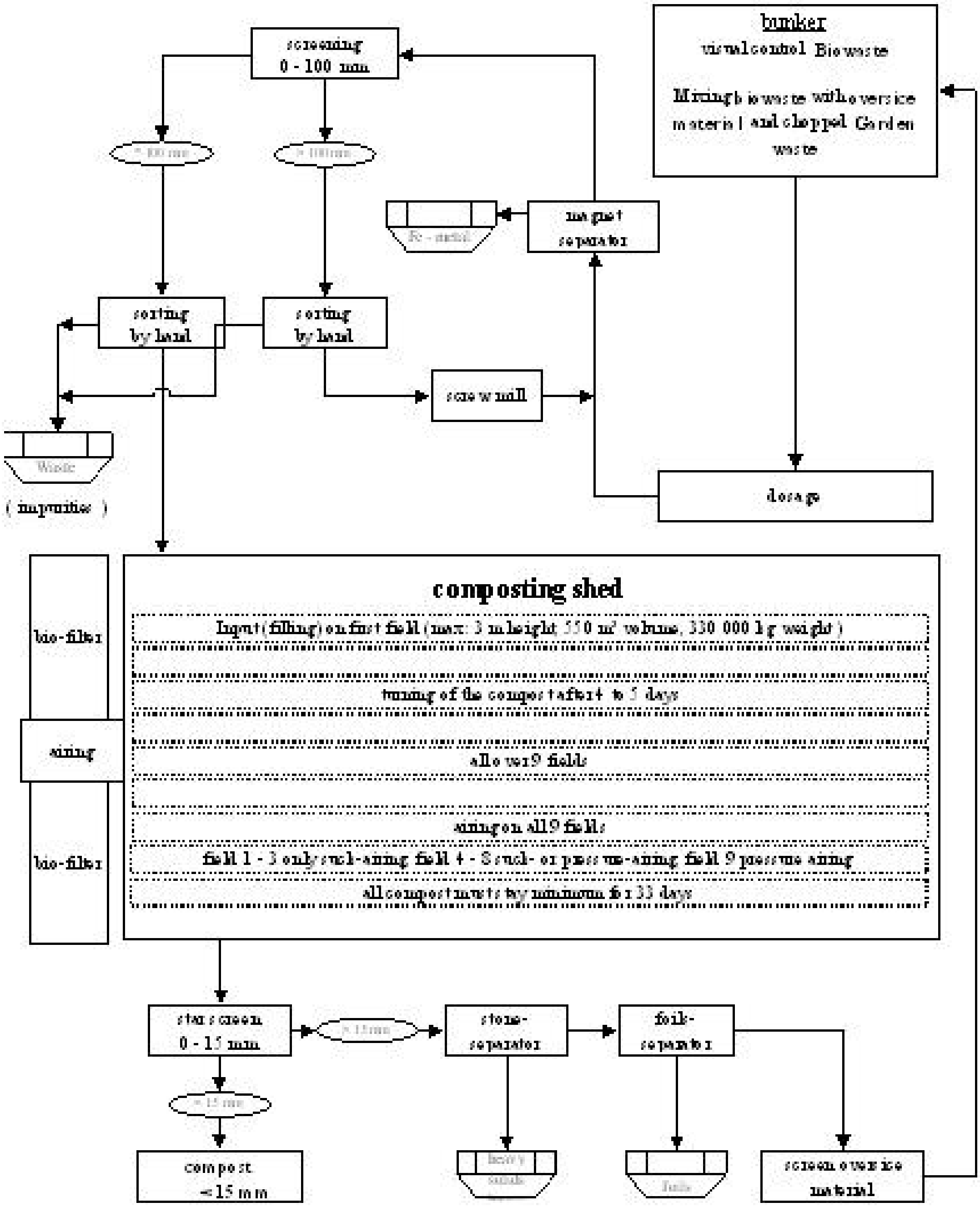
**Compost Storage -** Mature compost is stored until it is sold to the customer.

### Process Schematic




### Technology Picture

## Flow Chart


bunker
visual control Biowaste
Mixing biowaste with oversize material and chopped Garden waste
screening
0 - 100 mm
magnet
separator
sorting
by hand
sorting
by hand
screw mill
( impurities )
dosage
composting shed
Input (filling) on first field (max: 3 m height, 550 m³ volume, 330 000 kg weight)
turning of the compost after 4 to 5 days
all over 9 fields
airing on all 9 fields
field 1 - 3 only suck-airing field 4 - 8 suck- or pressure-airing field 9 pressure airing
all compost must stay minimum for 33 days
bio-filter
airing
bio-filter
star screen
0 - 15 mm
stone-
separator
foil-
separator
compost
< 15 mm
screen oversize
material

**Composting In-Vessel Vertical Flow - TEG**

**Process Outline**

The TEG system has a maximum capacity of 14,300 tons/year, a residence time of 42 days and a lifespan of 15 years

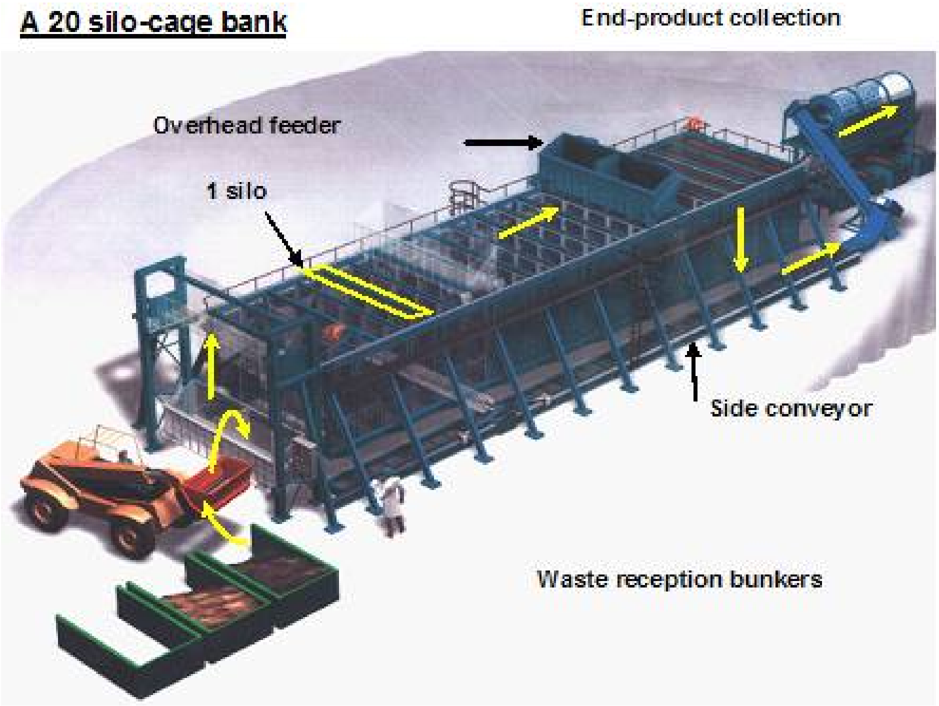
**TEG Silo-Cage Composting System -** The TEG Silo Cage (TSC) composting system provides for the rapid high temperature composting of organic wastes in a continuous flow plant. The insulated silos, each with a capacity of 32 $m^3$, are suspended above a concrete base in a large steel structure. A single silo-cage bank consists of between 8 and 28 silos, depending on the annual input or output requirements. For larger operations, multiple silo-cage banks are run in parallel. A silo-cage bank has a front-end mixer and loading system. An unloading system and side conveyor remove the composted material from the silo-cage. The back end of the silo-cage can be equipped with a screen and bagging line or the composted material can be collected and taken to a maturation barn to fully mature.

**Feedstock Delivery** - The organic waste is mixed with selected amendments in a predetermined ratio to give a feedstock that is ideal for composting. The amendment may need to be nitrogen-rich (e.g. manure) or carbon-rich (e.g. wood shavings) depending on the chemical composition of the waste. Amendment selection is crucial to ensuring that the feedstock material is bulky with sufficient airspace to support the aerobic microbial activity in all parts of the organic material. Each silo receives an amount appropriate to the operational requirements – typically about 3 $m^3$ per silo per day. The feedstock material is ‘sprinkled’ on top of the previous day’s load. The material drops no more than about half a metre into the silo and so its open structure is maintained.

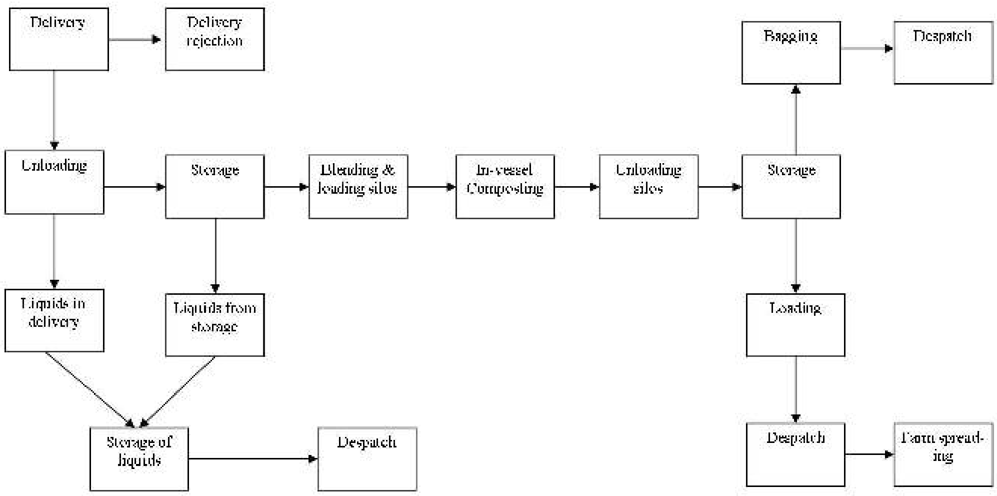
**Composting Silos** - The feedstock material sits on the hotter lower layers. It quickly warms, accelerating microbial activity and is rapidly colonised by micro-organisms from the already composting organic material below. As the silo is unloaded, the composting organic material gradually and evenly descends the silo and passes through a series of temperature bands. To monitor the progress of the process, the temperature in each silo is continuously measured by temperature probes and recorded on a pc-based data logger. The hottest layers in the silo tend to be between one and two metres from the top. As well as air in the bulky organic material, the vertical temperature gradient in the organic material creates a chimney effect and air is drawn up into the material from the open base of the silo. There is therefore no need for costly forced aeration, turning or agitation of the organic material. The feedstock characteristics and the end-product specifications determine the residence time in the silos, which can vary between 10 and 21 days.

**Unloading Composting Silos** - An unloading mechanism traverses beneath the silo-cage and extracts the bottom layer of composted organic material from the silos. The material is still warm (about 45°C) and side conveyors carry it to the end collection points. From here it may be dispatched straight to land or it may go to storage for maturation and further stabilisation in static piles before bagging.

## Process Schematic




## Flow Chart




## Technology Picture




**Composting In Vessel Batch Mobile with Enclosed Windrow – Vital Earth**

**Process Outline**

The derby site is one of two existing UK plants operated by Vital Earth Group. The process has a maximum capacity of 10,000 tons/year, a residence time of 54 days and a life span of 20 years. The plant utilises eight 40 $m^3$ capacity stainless steel mobile vessels. Each vessel houses an input and output blower controlled by a PLC to maintain pre-set temperatures through aeration of the composting pile. Temperature recordings are taken once per second and recorded for traceability. Each vessel has an integral leachate collection tank and an extractor pipe leading to a bio-filter. Materials are shredded and blended prior to being placed in the vessel with a single probe reading temperatures at the centre of the pile. Additional readings are taken in the lower outer corners of the composting pile.

During a seven-day retention period the pile temperature exceeds 70$^oC$ in accordance with EU ABP Regulations. Other temperature profiles include 65$^oC$ to open weed seeds and 46$^oC$ for maximum degradation during the mesophilic stage. The process control is accessible via a telephone line allowing technicians at head office to remotely monitor and adjust the parameters if required. The materials are tipped from the vessel after 7 days and screened to 6mm minus and 25mm plus. Materials measuring <6mm (approx 50%) are placed into a vermi-composting maturation process in wooden trays for a further 7 days. 6mm - 25mm materials are matured in housed 'forced aeration' static piles for 6 to 8 weeks. The oversize is reused to add porosity. Process traceability comprises of data recorded on a bar code system. Collected data includes - in-vessel batch number, waste sources, temperature profiles, pathogen test results and maturation test results. All bags leaving site are printed with a unique barcode relating to the aforementioned data. Traceability relates to 40 $cm^3$ batches.

## APPENDIX B –COST ANALYSIS

### Fuel Costs

| **Cheshire** | |
|---|---|
| | |
| Av. Food waste arisings per hhld (kg) | 3.08 |
| Av. Food waste arisings per hhld (tonnes) | 0.00308 |
| Av. Dist between houses (meters) | 17.71 |
| Total food waste collected annually (tonnes) | 10,000.00 |
| No of households visited | 3250871.81 |
| Distance travelled (meters) | 57557421.7 |
| Distance travelled (miles) | 35764.52 |
| | |
| Terberg ABUV food collector capacity (tonnes) | 3.5 |
| Utilisation % of vehicle | 80 |
| Corrected capacity | 2.8 |
| Trips required to collect 10000 tonnes food waste | 3572 |
| Minimum distance travelled per trip (miles) | 10.01 |
| | |
| Volume of fuel consumption while full (litres per mile) | 0.83 |
| Volume of fuel consumption while empty (litres per mile) | 0.55 |
| Volume of fuel consumption for collections (litres per 100 km) | 69.05 |
| Volume of fuel consumption for collections (litres per km) | 0.69 |
| Volume of fuel consumption for collections (litres per mile) | 1.11 |
| Calorific value of diesel (kWh/litre) | 10.8 |
| Fuel emission factor (kg $CO_2$/kWh) | 0.25 |
| | |
| Land area (sq km) | 2083.00 |
| Land area (sq miles) | 804.25 |
| Number of facilities | 1 |
| Indicative distance to facility (miles) | 28.36 |
| | |
| Distance from depot to collection start (km) | 5 |
| Distance from depot to collection start (miles) | 3.11 |
| Minimum distance for collection (miles) | 10.01 |
| Distance from collection end to facility (miles) | 28.36 |
| Return distance from facility to collection end (miles) | 28.36 |
| Collection end to depot (km) | 5 |
| Collection end to depot (miles) | 3.11 |
| Distance travelled per trip (miles) | 72.94 |
| Distance travelled to collect 10,000 tonnes food waste (miles) | 260585.93 |
| | |
| Volume of fuel consumption depot to collection start (litres) | 1.70 |
| Volume of fuel consumption for collection (litres) | 11.13 |
| Volume of fuel consumption collection end to facility (litres) | 23.51 |
| Volume of fuel consumption facility to collection end (litres) | 15.51 |
| Volume of fuel consumption collection end to depot (litres) | 1.70 |
| | |
| Volume of fuel consumption per trip (litres) | 53.55 |

| | |
|---|---|
| Total volume of fuel consumption (litres) | 191306.15 |
| Cost of fuel per litre | £0.90 |
| | |
| **Total cost of fuel** | **£172,175.53** |

### Vehicle Costs

| **Vehicle Costs** | |
|---|---|
| | |
| Trips per Year | 3572 |
| Trips per Week (5 day) | 70.05 |
| Trips per Day | 14.01 |
| Distance Travelled per Trip (miles) | 72.94 |
| No of households visited per trip | 909.99 |
| Trips per Vehicle per Day | 1 |
| No of Vehicles Required | 14.01 |
| | |
| Lease cost per vehicle (£/month) | £800 |
| Lease cost per vehicle (£/year) | £9,600 |
| Total lease cost (£) | £134,491.43 |
| | |
| Operational cost per driver | £22,000 |
| Total cost of drivers | £308,209.52 |
| Operational cost per loader | £17,000 |
| Total cost of loaders | £238,161.90 |
| 12 months road tax | £1,000 |
| 12 months insurance | £750 |
| RVC annual servicing and maintenance | £10,000 |
| Overheads; management, admin, office etc. | 10% |
| | |
| Total vehicle costs | £692,612.86 |
| | |
| Total vehicle costs including overheads | £761,874.14 |

### Project Delivery Costs

| | |
|---|---|
| Site identification min | £15,000 |
| Site identification max | £20,000 |
| Average site identification | £17,500 |
| | |
| Planning and EIA for AD | £100,000 |
| | |
| Procurement non-PFI min | £250,000 |
| Procurement non-PFI max | £500,000 |
| Procurement non-PFI average | £375,000 |
| | |
| Procurement PFI min | £500,000 |
| Procurement PFI max | £1,000,000 |
| Procurement PFI average | £750,000 |

| | |
|---|---|
| Average procurement | £562,500 |
| | |
| Total costs min | £365,000 |
| Total costs max | £1,120,000 |
| Average total costs | £680,000 |
| | |
| Life span (years) | 20 |
| | |
| **Average total costs per year** | **£34,000** |

## Landfill Costs

| | |
|---|---|
| Waste sent to landfill (tonnes) | 10,000 |
| Cost of transport | £934,049.68 |
| | |
| Time period for project delivery (months) | 18.00 |
| Time period for project delivery (years) | 1.50 |
| Waste sent to landfill over time period (tonnes) | 15,000.00 |
| Waste sent to landfill per year of lifespan (tonnes) | 750.00 |
| | |
| **Cost of transport for waste sent to landfill/year** | **£70,053.73** |