Feasibility Study
Concerning Anaerobic Digestion
in Northern Ireland

Final Report for
Bryson House, ARENA Network and NI2000.

Funded by NIE and Better Belfast

eunomia
research & consulting

EXECUTIVE SUMMARY

This study has sought to examine the feasibility of making use of AD systems for the treatment of MSW in Northern Ireland. The study's scope has been quite broad, and this has made it difficult to examine all possibilities. We have concentrated, in the study, on the source separated organic fraction of municipal waste. In some respects, this is the most difficult feasibility test. Feasibility may be enhanced if other waste streams are co-digested. To this end, to the extent that our conclusions are favourable, they are likely to be more so if one takes account of the possibilities for co-digestion.

Processes Available

There are a very large number of processes now available, and there are a growing number of systems in place across the EU. These include wet and dry processes, and processes operated at mesophilic and theormophilic temperatures. Most are still one-stage processes.

The Policy Environment

Generally, the policy environment is favourable to the development of AD. In Northern Ireland:

- The Northern Ireland Heritage Service is reviewing its waste strategy;
- The Northern Ireland Heritage Service is developing its strategy for dealing with biodegradable wastes. This reflects concerns to ensure that the country can meet targets for biodegradable municipal waste under Article 5 of the Landfill Directive, as well as the broader commitments contained in the Directive to ensure a reduction in landfilling of all biodegradable wastes;
- The Department of Enterprise, Trade and Investment (DETI) is developing a strategy for the promotion and development of renewable energy, including mechanisms for enhancing the price received for electricity derived from renewable sources (through what amounts to a system of tradable credits, or green certificates);
- There is some interest, on the part of the principal electricity supply company NIE, in reinforcing parts of the electricity network which are weak.

At the European level, various initiatives at the European level, whilst seeking to ensure that waste derived soil improvers are unlikely to transmit pathogens, are encouraging source separation of biowastes so as to provide feedstocks for the production of quality composts. These include:

- The 2nd Draft of a Biowaste Directive;
- the European Commission's Communication to the Council and the Parliament *'Towards a Thematic Strategy for Soil Protection'*.
- The Discussion Document issued by the European Commission concerning Biowastes and Sludges.

Some issues remain of concern. These include the way in which anaerobic digestion is defined (for the purposes of, for example, the setting of targets for recycling and 'composting'), and the links (or rather, the lack of them) between standards for end products and the freedom to spread composted / digested materials on land.

Regulatory Issues

One piece of legislation deserves some attention. This is the UK ABPR. This lays down process requirements for AD and composting plants and requires HACCP plans to be prepared for all sites (to ensure that unprocessed material cannot cross-contaminate 'clean', i.e., treated material).

AD plants seem well-adapted to the UK ABPR, possibly more so than most compost plants (because of the enclosed nature of the process, and the 'one-way-flow' nature of the treatment). Hence, the UK ABPR possibly has the effect of narrowing cost differentials between composting and AD facilities.

Case Studies and Plant Analysis

The case studies and plant analysis highlight the possibilities for AD of source separated organic wastes in different contexts.

The plant analysis shows considerable variation in performance (in respect of biogas generation) and in the unit capital costs. This cautions against any easy generalisations of AD processes. Different suppliers seek to make use of residues in different ways, whilst the UK ABPR might require some re-design of processes for different suppliers. Such re-design should not be too onerous given the nature of the requirements, and the nature of digestion processes (frequently generating some heat on site).

On the basis of the financial analysis, the costs for AD are still likely to be higher than for aerobic composting processes. Lower end gate fees for AD – we would expect these to be £40-50 - would correspond with higher end gate fees for aerobic plants. This may imply a need for innovative approaches for integrating AD into waste management systems, or a need to seek to reduce unit costs through co-digesting other appropriate materials.

Much depends upon the approach adopted by local authorities, and the significance accorded to the development of alternative sources of energy supply. The analysis could be altered by support through Programmes such as SMART 2, and whilst enhanced capital allowances might be available for good quality CHP, we would expect the effect of ECAs to be of relatively low significance. More important will be the prices received for electricity supplied, and for the residues.

Economics of Digesting Source Separated Organic Fractions of MSW

Recognising the cost differentials which are likely to remain between composting and AD, we sought to show how maintaining distinct collection systems for garden waste and for kitchen wastes can reduce the cost differential between composting-only systems, and those including AD. This is based upon two key points:

1. The separate collection of biowastes can be an effective tool for cost-optimisation in collection and treatment; and

2. Aerobic systems have to incorporate structural material in the process. AD systems may not (some see it as more desirable than others), though they may need such material in post-treatment aerobic stabilisation.

The importance of biowaste collection and management systems is increasingly well understood. We sought to show how innovative systems are now available for implementation which:

- maintain costs at low levels; and

- ensure that there is no undue increase in collected waste through offering free garden waste collections to households.

We then sought to illustrate how:

a. by considering the collection system as a system, and notably, by considering the integration of biowaste and refuse collections, the costs of separate collection can be kept close to those of existing collection systems;

b. by aiming for high captures through separate collection, because the options for residual waste management are becoming more expensive, the costs of separate collection systems can be kept below what they will otherwise be if the system simply revolves around refuse collection and disposal;

c. by keeping the garden and kitchen waste collections separate, not only is the collection system cost-optimised, but so is the treatment of the biowastes; and

d. last but not least, even where one takes the view that there remains a cost differential between composting and AD, AD can be part of a system which is cheaper than some involving separate collection of kitchen and garden waste for composting only.

These conclusions are of significance. They point the way towards truly integrated waste management. AD can have a role to play in sustainable systems of this nature without incurring cost penalties. Evidently, however, the choice of AD system has to respect the nature of the input feedstocks.

Environmental Performance

Environmentally, most studies support the view that AD is superior to composting. The principal reason is related to the generation of energy and the benefits this confers.

Some studies have questioned the degree to which AD should be preferred to good quality incineration. Most of these studies are based upon proposals for collection logistics which simply do not make sense (and differ radically from the cost-optimised proposals we have suggested). Even in these cases, a preference is difficult to discern.

There remain questions as to the degree to which incineration of wet fractions such as kitchen wastes makes any sense at all. Moisture contents are frequently in excess of 70%, implying that what one is sending for combustion is principally water.

As long as collection logistics are optimised, and source separation is such as to ensure quality end products, separate collection of biowastes makes financial and environmental sense. Whether AD is considered superior to composting in an overall analysis has typically been considered a question of cost. In the past, and to some extent still, AD has been more expensive than aerobic treatments. However, as we have sought to demonstrate, canny approaches to cost-optimised collection can fit well with the deployment of AD in waste management systems. Furthermore, the UK ABPR, particularly as it applies to non-catering waste Category 3 material, may make AD an attractive option for these materials.

Is Digestion of MSW Feasible in Northern Ireland?

The short answer to this question is a qualified yes. This is likely to be true for both source-separated organic fractions of MSW (SOFMSW) and the organic fractions of MSW separated from residual waste (OFMSW). In the latter case, there will be question marks over the quality of digestate product produced, both in respect of heavy metal contamination, but also, and perhaps more importantly, in terms of organic contaminants.

Digestion systems are especially interesting in the context of the twin objectives of moving MSW away from landfill, and in seeking to develop supplies of renewable energy. MSW has to move away from landfill-based systems, and not before time, because of the Landfill Directive (and the Northern Ireland Environment and Heritage Department has recently consulted upon the implementation of a landfill allowances trading scheme to ensure compliance with the Directive). In this context, the question, 'where should biodegradable municipal waste be diverted to?' assumes great importance.

For biowastes, the options are, broadly:

1. systems based around source separation, with material being either composted or digested;

2. systems based upon mixed waste management, with material being treated through conventional incineration;

3. systems based upon mixed waste management, with material being treated through advanced thermal reatment; and

4. systems based upon mixed waste management, with material being treated through mechanical biological treatment, wither with or without and AD component, and with or without the production of a refuse derived fuel from the high-calorific residual wastes (including non-biodegradable elements, such as plastics, for which ROCs are not available).

AD probably offers the most popular means of recovering energy from waste diverted from landfill. It can also provide valuable products for use in agriculture. The relatively dispersed population in Northern Ireland does not obviously lend itself to centralisation of waste treatments. Options based upon conventional incineration are unlikely to be either popular, or especially well-suited to the situation in hand (not least since significant economies of scale are unlikely to be available even in the centres of population of Northern Ireland).

These considerations, alongside the fact that a range of other biowastes are likely to be available, makes AD a very interesting technological option for waste management in Northern Ireland. It fulfils the requirements – simultaneously – of both renewable energy strategies and waste strategies, whilst it lacks the poor public image of incineration technologies.

With careful design of collection systems, digestion can play a role in treating the material collected through high capture, cost-optimised collection systems. Suitable market development activities would complement well the development of this technology. The market development process itself will be helped by a focus on high quality products (and hence, appropriate feedstocks) so as to give confidence to end users of what is a very valuable material for application to land.

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Glossary of Terms

The following are definitions of terms used in this report:

Anaerobic Digestion: The process by which biological material is broken down by bacteria in the absence of oxygen. It occurs in enclosed vessels (in this case, reactors, or digestion tanks).

Biogas: The gas produced by anaerobic bacteria in the anaerobic digestion process. Typically, it is composed primarily of methane and carbon dioxide, with low levels of other gases such as ammonia, hydrogen sulphide, hydrogen and water vapour.

Biogas Production Rate: The biogas production rate is the volume of biogas, at standard temperature and pressure, that can be produced per unit mass of digestion input. It is expressed in this report as m3 / tonne of waste to digestion.

Biochemical Oxygen Demand (BOD): A measure of the organic strength of a wastewater stream, and indicates the amount of biodegradable compounds in the stream.

Biosolids: The product that remains after sewage sludge has been biologically stabilized through means such as anaerobic digestion.

Biowastes: The term used to describe kitchen and garden wastes, as well as similar materials from commercial and industrial sources.

Clarification: The process by which heavier solid particles are removed from wastewater by settling.

Comminution: The process of size reduction in waste pre-treatment systems.

Digestate: The dewatered solid material resulting from anaerobic digestion of organic materials.

Digester Capacity: In this report, the digester capacity is defined as the useable volume in the digester.

Effluent: The liquid end-product of a treatment process such as anaerobic digestion. It is sometimes referred to in this report as wastewater, or liquor.

Flare: A device for burning off excess biogas without recovery of heat or other form of energy.

Greenhouse Gas: A gas that contributes to the insulating layer of the earth's atmosphere, which is implicated in predicted climate change effects.

Mespophilic: A specific temperature range in which AD reactions may take place, nominally 25°-40°C, but usually around 35° C

Methanogenesis: The generation of methane in landfills and in AD by anaerobic processes.

Municipal Solid Waste (MSW): Solid waste originating from a municipality, composed primarily of household waste.

Retention Time: The average amount of time that material remains in the digester. It is a parameter used to determine adequate digestion. It is a function of flow and digester volume (digester capacity) according to the formula below:

Retention Time = V / Q

Where V = Digester volume (capacity) in m^3

Q = Flowrate in m^3/d

Organic Fraction of Municipal Waste (OFMSW): The term used in this report to describe organic wastes (kitchen scraps, nonrecyclable paper, animal wastes and sanitary wastes) which are separated from mixed waste collected from householders.

Source Separated Organic Fraction of Municipal Waste (SOFMSW): The term used in this report to describe source-separated household organic wastes (kitchen scraps, nonrecyclable paper, animal wastes and sanitary wastes) which are to be collected from householders.

Thermophilic: A specific temperature range in which AD reactions may take place, nominally 45°-65°C, but usually around 55°C.

Total Solids (TS): The amount of dry solids in a material. This includes both the organic and non-organic fractions of the solids. It is expressed in two ways in the appendices to this report:

I) As a concentration, in percentage of the weight of the total sample.

II) As an absolute amount, in tonnes.

Volatile Solids (VS): The organic, or carbon-containing, fraction of TS. VS concentration is expressed as a percentage of the TS. It is determined by incineration of the sample at 5500°C; volatile solids burn off while the fixed solids (non-organic fraction) will remain in the sample.

Biodegradable Volatile Solids (BVS) is a subset of Volatile Solids and is comprised of that fraction of the volatile solids which is degradable by bacteria during the reference time frame. It is determined by lab tests of biodegradability of the material.

1.0 INTRODUCTION

Eunomia Research & Consulting is pleased to have been asked by ARENA Network, Bryson House and NI2000 to carry out a feasibility study, funded by Better Belfast and NIE, concerning the potential for using anaerobic digestion (AD) systems to treat municipal waste in Northern Ireland.

The study seeks to assess the feasibility of AD systems alongside a more general assessment of the better known, and more common (for municipal waste treatment) aerobic processes, some of which have already been adopted within Great Britain and Northern Ireland. This is an important piece of work since it cuts across two of the key environmental objectives for Northern Ireland, the sustainable management of wastes, and the provision of cleaner forms of energy from renewable sources.

The timing of the study could not be more apt. Several processes which are underway make this study especially timely:

- The Northern Ireland Environment and Heritage Service (EHS) is reviewing its strategy for dealing with biodegradable wastes.[1] This reflects concerns to ensure that the country can meet targets for biodegradable municipal waste under Article 5 of the Landfill Directive, as well as the broader commitments contained in the Directive to ensure a reduction in landfilling of all biodegradable wastes. A consultation document concerning the allocation of Landfill Allowances, in line with proposals under the Waste and Emissions Trading Act, has already been issued, and the responses analysed;

- EHS is also in the process of reviewing the NI Waste Management Strategy, which was published in March 2000;

- The Department of Enterprise, Trade and Investment (DETI) is developing a strategy for the development of renewable energy technologies, including mechanisms for enhancing the price received for electricity derived from renewable sources (through what amounts to a system of tradable credits, or green certificates);

- There is some interest, on the part of the principal electricity supply company NIE, in developing supply in parts of the network which are weak; and

- Various initiatives at the European level, whilst seeking to ensure that waste derived soil improvers are unlikely to transmit pathogens, are encouraging source separation of biowastes so as to provide feedstocks for the production of quality composts.

In conjunction with the more widely recognised benefits of managing waste more sustainably, and increasing the proportion of energy supplied from non-fossil fuel sources, these drivers and concerns make this study especially relevant to the current situation in Northern Ireland.

[1] The EHS is the government agency primarily responsible for development and implementation of the Waste Management Strategy for Northern Ireland.

2.0 OBJECTIVES

The broad objectives of the work were established as follows:

- To provide a review of established and emerging AD technologies;
- To carry out a desktop study of existing reports and case studies, with reference to examples in the UK and world wide;
- To review legislation on waste treatment and the fate of end products, especially those related to the EU Animal By-products Regulation;
- To provide an analysis of at least 4 technologies with reference to:
    - The physical characteristics of the processes (land take, method of gas storage)
    - Economics / financial viability (including, e.g. issues around selling electricity into the grid, revenues from use of residues, economies of scale)
    - Cost of installation and maintenance
    - Degree of assurance with respect to compliance with existing legislation (especially Animal by-product issues);
- To provide an assessment of the issues around the suitability of digestate for application to land or other uses;
- To provide an assessment of the issues around the suitability of applying liquid residues ('liquor') to land or in other uses;
- To review approaches to the collection of domestic organic wastes (with reference to logistics and suitability of collected materials for treatment);
- To discuss issues pertaining to plant location (in the context of what might be considered, hypothetically, as a regional strategy for AD)
- To review the environmental impacts of AD systems;
- To compare, in broad terms, the AD approach with aerobic approaches. This will include listing suppliers, assessing costs, and reviewing most of the issues discussed above as they apply to aerobic treatments.

This is an extensive list of objectives. Given the available time and resources, some scoping of these was necessary. The study focuses principally upon anaerobic processes. These are less well known in the UK setting, and since aerobic processes for treating fractions of municipal waste are already known to be (demonstrably) 'feasible', more is to be gained through improving our understanding of anaerobic treatments of biodegradable waste. In-depth analysis of AD systems will however provide information that will allow the relative merits of anaerobic approaches to be assessed against aerobic composting processes.

One of the key issues that face the study, in terms of scoping, is the fundamental question of how to deal with the different possibilities for dealing with the various materials for which treatment by AD is suitable. One can consider two extremes in terms of a regional strategy:

- A highly decentralised system, in which, for example, small-scale digestion systems, usually on-farm, are used to treat animal slurries either with or without small quantities of source separated municipal biowastes; and

- A highly centralised system, in which larger / industrial scale facilities are used to treat a range of materials, possibly including municipal biowastes, sludges, etc.

Evidently, any regional strategy could deploy a mix of approaches, and there may be good reasons for doing so.

Globally, there are a vast number of the decentralised, on farm (even domestic) systems. Most of these installations (by number) are to be found in Asia. The technology tends to be relatively basic. It would be impossible to review all types of technology, though arguably, because of the basic nature of the systems, some form of generic description would be merited. However, it might be difficult for these systems to give adequate assurance to regulators that hygienisation requirements had been fulfilled, particularly given the rather stringent process requirements being laid down in EU and UK law. It should be noted that in EU Member States, including the UK, agricultural wastes have not, historically, been treated as 'controlled wastes'. As such, some of the pollution control legislation which affects controlled wastes has not affected the treatment of livestock residues. The relevant controls here have been through instruments affecting the management of nutrients, notably nitrates and phosphates. This situation is now changing, though the situation as regards manures and slurries is not yet completely clear. This may be covered under new exemptions from waste management licensing which treat landspreading of manures and slurries as a recovery option where they are deemed to be wastes.

On the other hand, the more centralised facilities, which might be more suitable for dealing with a range of controlled wastes, are required to comply with licensing and other legislation. Globally, there are far fewer AD plants of this nature, though the number is growing annually (and apparently, at an increasing pace).

Most UK 'feasibility studies' appear to have focussed on digestion systems for agricultural wastes. There are probably a number of reasons for this:

- They are more common;

- Until recently (and to some extent, this is still true), the costs of AD for controlled wastes (e.g. municipal wastes) have been viewed as prohibitive. Competing treatments, including composting, have been lower in cost. This is now changing since:

    - the Landfill Tax is increasing landfill costs. The tax is due to increase by at least £3 per annum from its current level until it reaches a level of £35 per tonne;

    - the UK Animal By-products Regulation[2] (henceforth referred to as the UK ABPR) may have a differential impact upon the costs of composting and AD, increasing unit costs of composting more than those for AD;

    - the same Regulation essentially outlaws the landfilling of former foodstuffs from the end of 2005. This means that other management routes for such materials must be found.

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[2] Statutory Instrument 2003 No 1482: *The Animal By-products Regulations 2003*, London: HMSO.

- There has been a perception (not without foundation given the way in which AD technologies have developed) that AD is most suitable for dealing with the wet biowastes (rather than wastes with a higher solids content, such as those from the municipal stream);

- Progress in the source separation of biowastes has been slow in the UK, hindered by low 'avoided disposal costs'. This is now changing due to various targets and other legislative and financial drivers.

Given that there have been a number of studies in Northern Ireland looking at the introduction of AD plants using agricultural and various industrial food wastes, the major focus of the study is on municipal wastes. We therefore propose that the study addresses the feasibility of larger digestion systems where a principal feedstock is municipal waste. For these systems, specific plant analysis will be undertaken. Note that these results will need to be presented in ways which do not compromise the confidentiality requirements of the providers of the information.

The above discussion informs the approach adopted in the rest of this study:

- ➢ A focus on anaerobic treatments, though with an eye to comparing performance with aerobic treatments;

- ➢ A focus on commercial scale systems; and

- ➢ A focus on treatment of municipal wastes.

3.0 OVERVIEW OF AD AND ITS ROLE IN TREATING MUNICIPAL WASTES

Anaerobic digestion (AD) is the bacterial decomposition of organic material in the (relative) absence of oxygen. The main products are biogas (comprising principally carbon dioxide and methane), as well as a reduced mass of bacterial biomass. The process proceeds through a series of stages. Illustrations of this (in increasing levels of complexity) are shown in Figure 1 and Figure 2.

Figure 1: Basic Schematic of AD Process

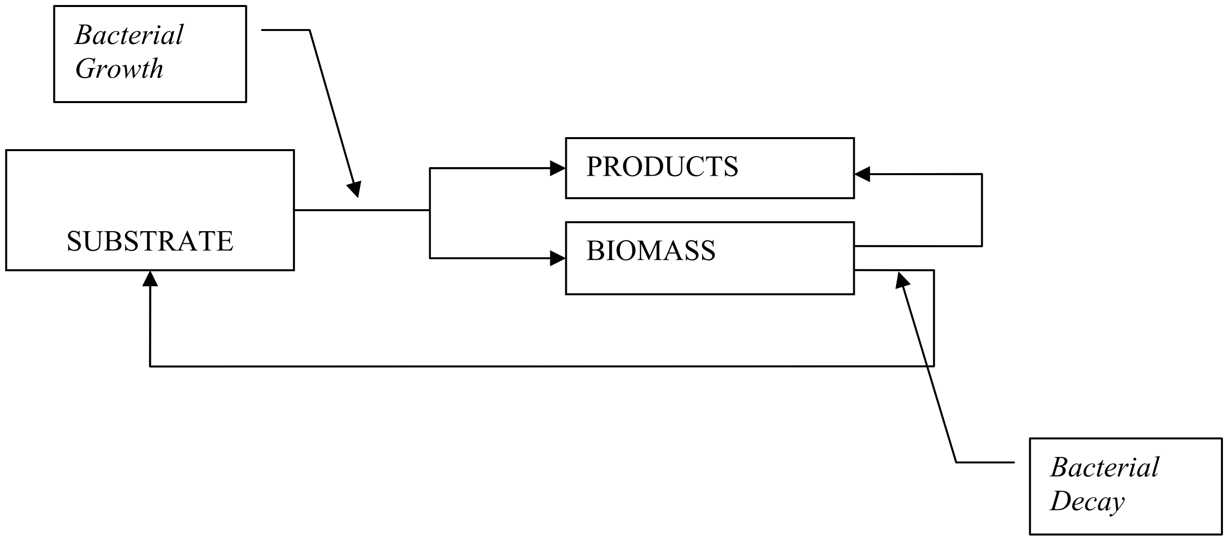
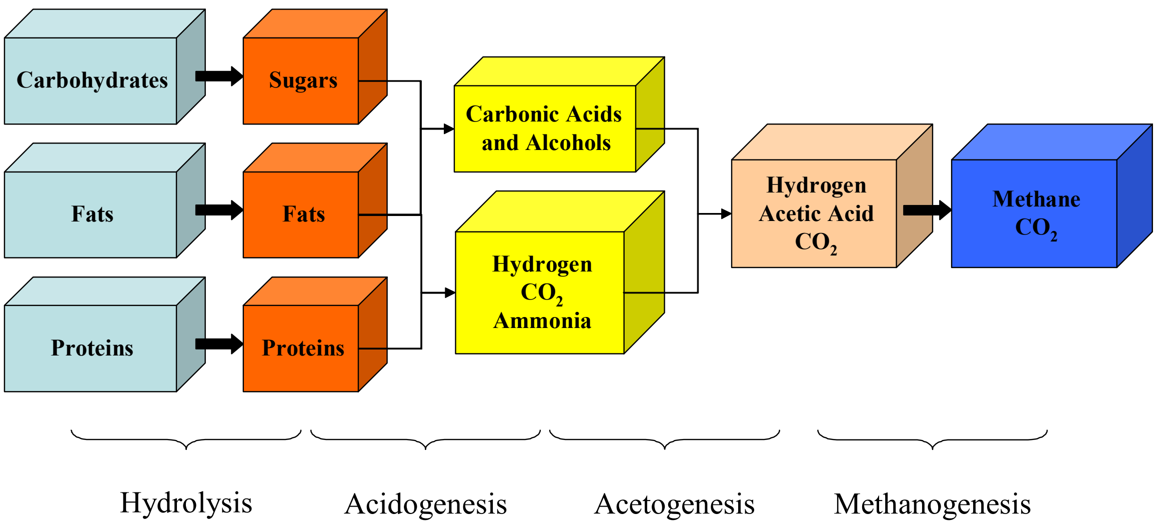


Figure 2: Breakdown of AD Process into 'Classical' 4-stage Process



Source: T Al Seadi (2001) Good Practice in Quality Management of AD Residues from Biogas Production, IEA Bioenergy Task 24, Energy from Biological Conversion of Organic Waste.

Traditionally, AD has been used to treat liquid wastes with or without suspended solids, such as manures, domestic or industrial wastewaters, sludges from biological or physio-chemical treatments etc.

Solid wastes, such as those from agricultural and municipal waste, have been a relatively recent focus for applications of AD. Yet the significant organic matter content of these wastes suggests considerable potential for biogas production. Furthermore, some of these wastes, though solid, have high moisture content, and therefore appear distinctly unattractive (ecologically) for other energy recovery techniques such as incineration.[3]

Studies looking at AD of municipal waste began in the early 1970s, frequently looking at the potential for co-digestion with other materials such as sludges and manures. The mid 1970s also saw some assessment of the possibilities for digestion of mixed MSW (to address the problem of relatively uncontrolled methanogenesis in landfills). European studies on solid waste digestion tended to lag US studies, but a key difference was that European studies tended to focus more (though by no means exclusively) on AD of a *separated* organic fraction of MSW (SOFMSW).

The high degree of flexibility associated with AD is claimed to be one of the most important advantages of the method, since it can treat several types of waste, ranging from wet to dry organic wastes, and from clean organics to organic fractions of residual waste. The suitability of the method for very wet materials, for instance, has been addressed as an important feature in those scenarios where source separated food waste cannot be mixed with sufficient quantities of bulking agents such as garden waste (this is the case in some metropolitan districts). In such circumstances, the lack of structural materials makes aerobic composting less viable (from a technical perspective) as a treatment process.

AD of MSW has been commercially available for more than 10 years and in that time, the heterogeneous and variable nature of the feedstock has given rise to a considerable number of different processes in operation in many different countries.

3.1 Types of Digestion Plant

Generally, anaerobic digestion plants, whilst the reactor is central to the overall process, have to be considered as much more than 'just' the reactor itself. Figure 3 shows some typical unit processes which may be involved. Broadly, however, anaerobic digestion involves three stages:

- pre treatment;
- anaerobic digestion; and
- post-treatment.

3.1.1 Pre-treatment

In general, the nature of pre-treatment will depend upon the quality of separation of the feedstock which is anticipated. Just as with composting, accurately segregated fractions make materials handling much easier. Even SOFMSW usually requires further separation to remove wrongly sorted materials such as plastics, metals and oversized components.[4] Separation can be carried out under wet or dry conditions (see below).

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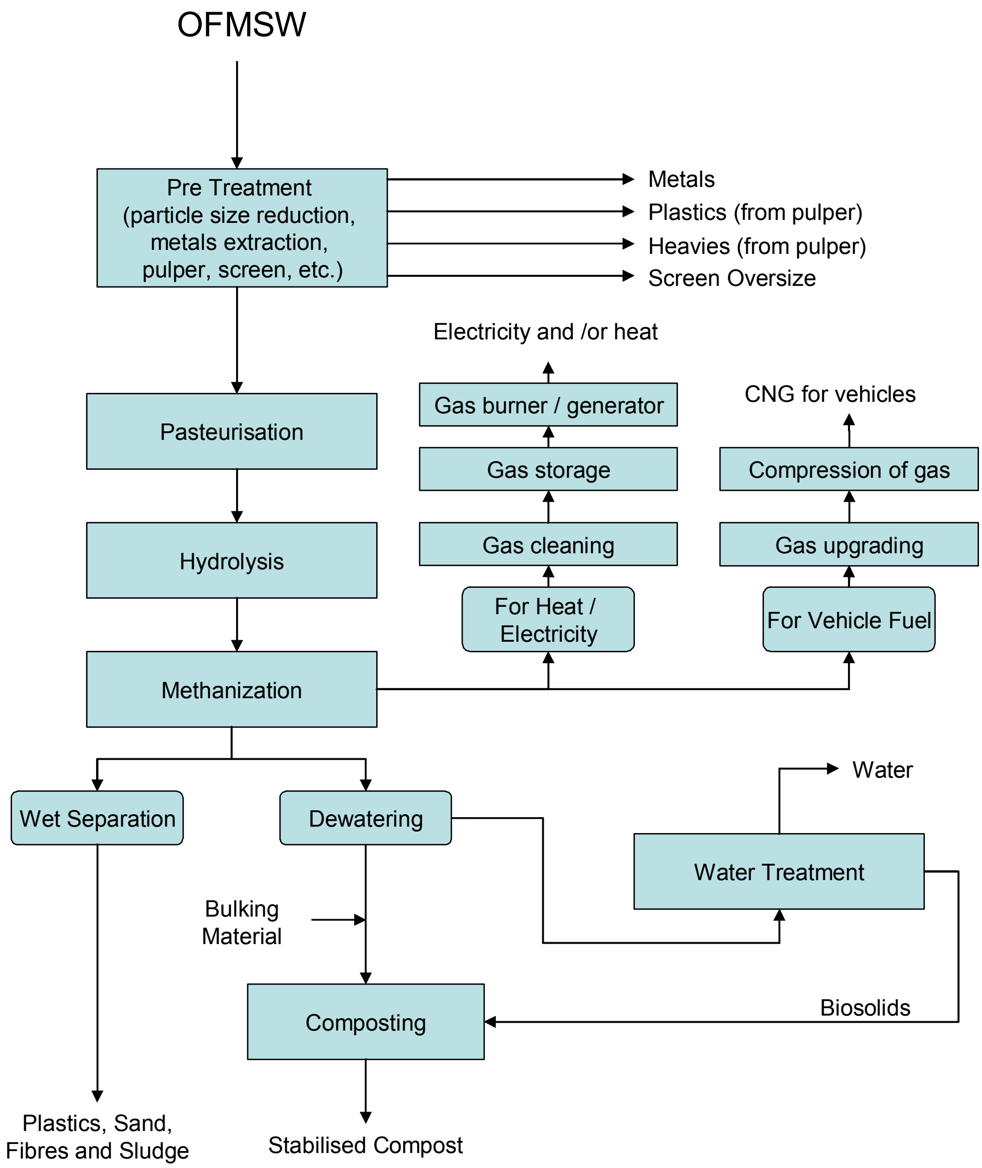
[3] However, it should be recognised that because incinerators tend to be run (at least in UK local authorities) on a gate fee basis for treating wastes (as opposed to being run as power stations), the low calorific value of some wet wastes makes them rather attractive to some operators since this allows greater throughput of wastes at the 'design' firing rate. Hence, contrary to popular opinion, operators of incinerators rather like these wetter wastes for commercial reasons, though from the perspective of energy generation, it makes little sense to combust them.

[4] Note that this is a consequence of the technical features of the AD process which requires coarse inerts to be removed. This is not always necessary at composting plants as long as separation achieves a purity in excess of 95% or so. Below such levels of purity, pre-screening becomes necessary at compost plants too.

Figure 3: Examples of Unit Processes Commonly Used in Conjunction with AD Processes for the Organic Fraction of MSW



After initial separation of materials, a process of size reduction is used to create a more homogenous material which will aid fermentation and facilitate processing. When considering substances like the organic fractions of municipal waste, whether source separated (SOFMSW) or not (OFMSW), one is considering a substance with a particulate nature. The accessibility of hydrolytic microorganisms to solid matter and the hydrolysis of complex polymeric components can constitute a rate-limiting step for the overall process. Hence:

> *Size reduction of the particles and the resulting increase of available specific surface, represents an option for increasing degradation yields and accelerating the digestion process.*[5]

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[5] J. P. Delgenes, V. Penaud and R. Moletta (2003) Pretreatments for the Enhancement of Anaerobic Digestion of Solid Wastes, in J. Mata-Alvarez (ed) (2003) *Biomethanization of the Organic Fraction of Municipal Solid Waste*, London: IWA Publishing, pp. 202-28.

Size reduction processes can include comminution and cell disintegration. Size-reduction usually implies screw-cutting, milling, drumming, pulping or shredding machines. Experimental evidence of the effect of size reduction through basic mechanical means has been reported by Hills and Nakano (for tomato waste), Palmowski and Muller (for vegetable mixes, meat, seeds, leaves and hay stems), and Hartmann et al (for manure) amongst others.[6] The results from the Palmowski and Muller study are shown below.

Table 1: Effect of Particle Size Reduction on Biogas Production and Digestion Time

Substrate	State of the Samples	Comminution Treatment	Improvement of Biogas Production	Reduction of Technical Digestion Time
Mixture of potatoes, apple and carrots	2x 2x2 cm pieces	Rubbed with a grater	-	50%
Meat	2x2x2 cm pieces	Ground with kitchen machine by cutting stress	2%	23%
Sunflower seeds	5mm pieces	Ground with kitchen machine by cutting stress	19%	45%
Maple leaves	2x2 cm pieces	Ground with flour mill by shear stress	14.4%	59%
Hay stems	1 x 5 cm pieces in water suspended	Ground in a stirred ball mill with water	18%	52%

Note: Technical digestion time = time to reach 80% of the maximal biogas production.

Source: L. Palmowski and J. Muller (1999) Influence of the Size Reduction of Organic Waste on their Anaerobic Digestion, II International Symposium on Anaerobic Digestion of Solid Waste, Barcelona, June 15 1999, pp.137-44.

3.1.2 Digestion

There are a number of different techniques falling under the definition of anaerobic digestion (AD). They are usually distinguished on the basis of:

- operating temperature (thermophilic plants operate at around 55°C and mesophilic at around 35 °C);
- the dry matter content of the substrate (dry systems with more than 20-40% dry matter, wet systems usually have less than 15% dry matter);
- the number of steps in the process, single-step or multi-step; and

[6] D. J. Hills and K. Nakano (1984) Effects of Particle Size on Anaerobic Digestion of Tomato Solid Wastes, *Agricultural Wastes*, Vol.10, pp.285-95; L. Palmowski and J. Muller (1999) Influence of the Size Reduction of Organic Waste on their Anaerobic Digestion, *II International Symposium on Anaerobic Digestion of Solid Waste*, Barcelona, June 15 1999, pp.137-44; H. Hartmann, I. Angelidaki and K. Ahring (1999) Increase of Anaerobic Digestion of Particulate Organic Matter in Full-scale Biogas Plants by Mechanical Maceration, *II International Symposium on Anaerobic Digestion of Solid Waste*, Barcelona, June 15 1999, pp. 129-36.

- whether the digester is continuously fed or whether a batch feeding system is used.

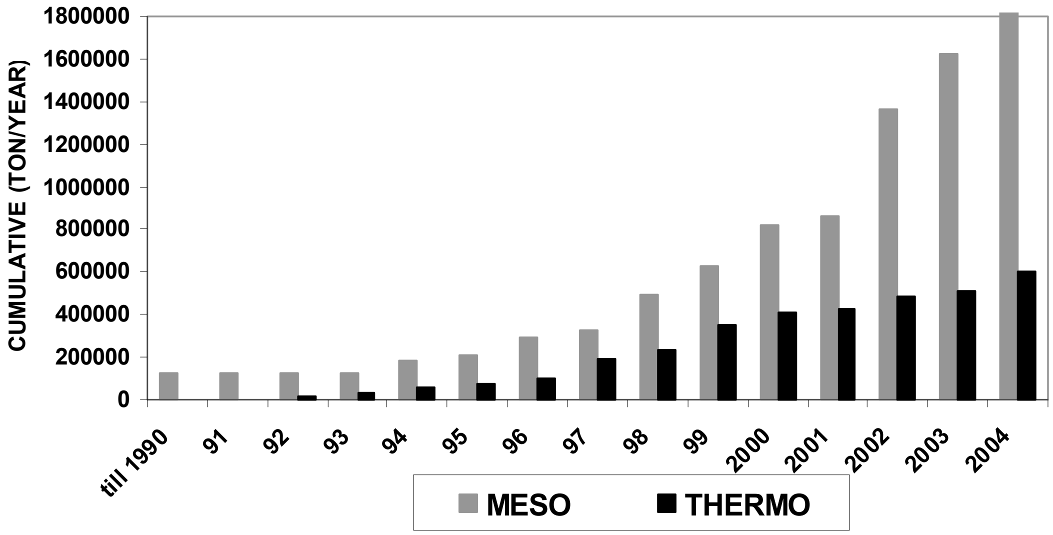
3.1.2.1 Temperature Range

AD can function over a large range of temperatures from so-called psychrophilic temperatures (around 10 °C) to extreme thermophilic temperatures (>70°C). Temperature influences the speed (kinetics) of anaerobic reactions. In particular, methanogenesis is strongly affected by temperature, with rates and yields increasing with temperature. Reactor temperature affects not only the reaction velocities of physico-chemical processes, but also, biochemical conversion rates.

The average value of temperature over a long time period fixes the bacterial population thus defining the two major groups of micro organisms. These are usually classified in association with two temperature ranges, around 35°C in the mesophilic range (25°C-40°C), and around 55°C (45°C-65°C) in the thermophilic range. A variation of reactor temperature within the specified ranges can change reaction velocity.

The vast majority of digestion, especially of OFMSW, is carried out in these two temperature ranges. De Baere indicates that in the year 2000, of the more than 1 million tonnes of installed capacity for digestion of the OFMSW, more than 600,000 tonnes was in the mesophilic range with thermophilic accounting for just less than 400,000 tonnes.[7] The development of thermophilic digestion capacity has, however, lagged the mesophilic, and over the 1996-2000 period, De Baere's figures suggest that mesophilic capacity has increased by only slightly more than thermophilic.

Figure 4: Shares of Mesophilic and Thermophilic Digestion Systems



Source: L. De Baere (2003) State of the Art Anaerobic Digestion of Municipal Solid Waste, paper presented at Sardinia Landfill Symposium, 2003.

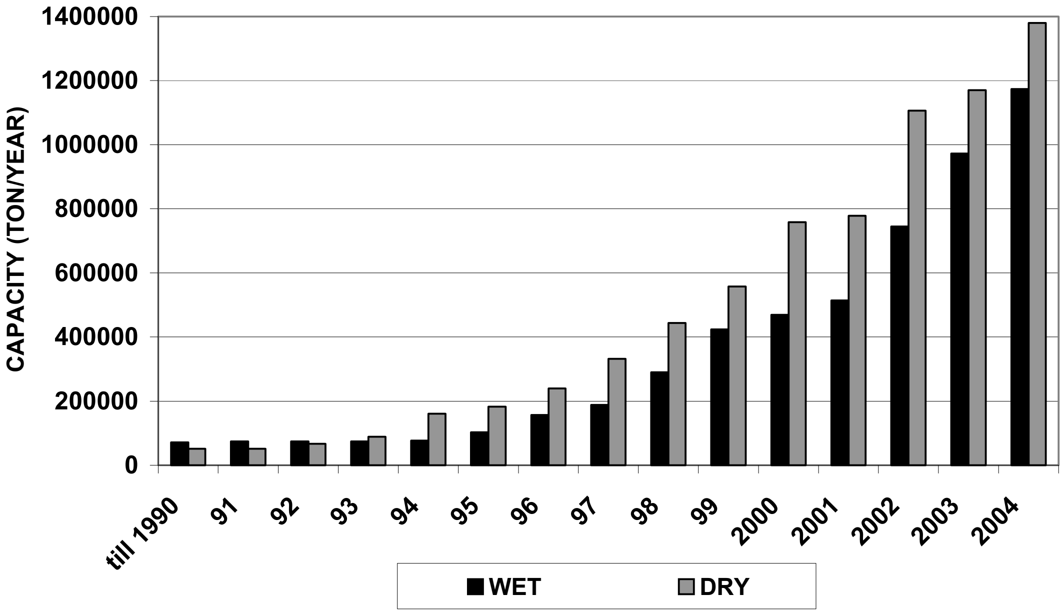
[7] L. De Baere (2000) State of the art of Anaerobic Digestion of Solid Waste in Europe, *Water Science and Technology*, Vol.41, No.3, pp.283-90.

3.1.2.2 Wet or Dry?

Wet digestion processes are carried out at a Total Solids (TS) content of no more than 15% by weight, most commonly within the range of 7-12% TS. Usually, water must be added to the feedstock at the slurrying stage to dilute the waste (organic materials range from 10-30% TS). The slurry can be pumped using positive displacement or rotary lobe pumps. Mixing in process tanks can be achieved by mechanical mixers within the tanks, or by gas mixing, using recirculated biogas, if TS in the digester is below 10%. Most wet digestion processes use a completely mixed reactor.

Dry digestion processes are carried out at a Total Solids (TS) content of over 15%, with 25-40% being the most common TS range. This material is too thick for liquid-handling pumps, and therefore dry digestion technologies use concrete pumps and screw conveyors. Mechanical and gas mixing equipment cannot usually handle the high solids concentrations of dry digestion, and therefore mixing is achieved by the configuration of the digester and recirculation of waste through the digester. The tank is usually a plug flow reactor, rather than a completely-mixed reactor as normally used in wet digestion.

Figure 5: Wet and Dry Systems



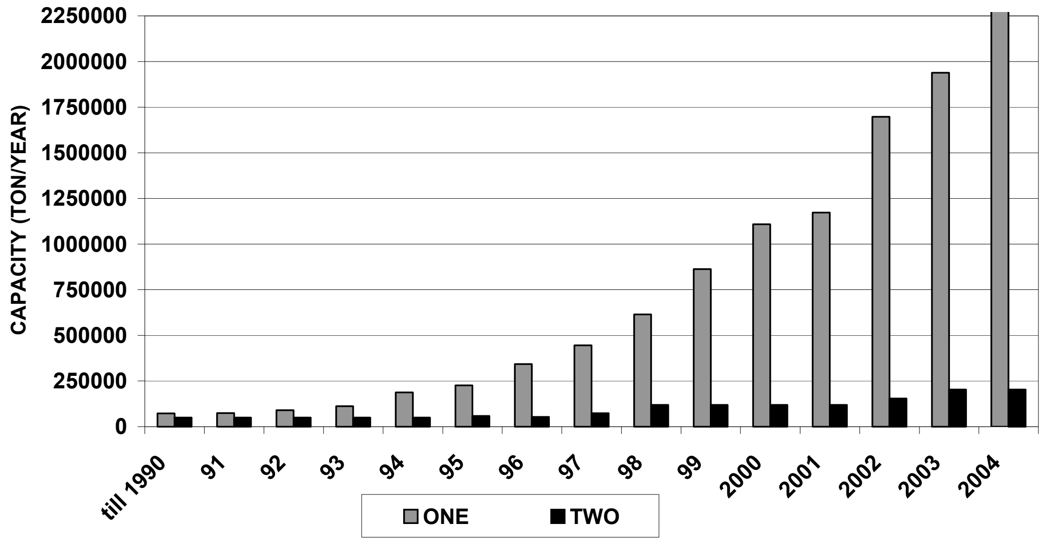
Source: L. De Baere (2003) State of the Art Anaerobic Digestion of Municipal Solid Waste, paper presented at Sardinia Landfill Symposium, 2003.

3.1.2.3 Single or Multi-step

As investigations concerning anaerobic digestion have proceeded, concerns regarding inhibitors of the reaction process, and as to what might be the rate-limiting step in the process have given rise to processes which, rather than occurring in one tank, are carried out in separate reactors in more than one stage. The rationale for this is that the conversion of OFMSW or SOFMSW to biogas is mediated by a sequence of reactions which are not necessarily optimized under the same conditions. Typically, two stages are used in which the first harbours the liquefaction-acidification reactions (with a rate limited by the hydrolysis of cellulose) and the second harbours the acetogenesis and methanogenesis, the rate of which is limited by the slow microbial growth rate. If the stages occur in separate reactors, the rate of methanogenesis can be enhanced through biomass retention schemes (or other means) whilst the rate of hydrolysis can be speeded up through using microaerophilic conditions.

Various reactor designs have emerged over time. However, although in theory, the design of multi-stage systems should improve performance, in practice, the main advantage appears to be reliability in treating wastes which exhibit unstable performance in single-stage systems. Amongst these more problematic materials are those with very low C/N (Carbon/Nitrogen) ratios, such as market / wet kitchen wastes. Hence, Bernal et al observed that, under thermophilic conditions, if the feedstock has high biodegradability (as with market wastes), the rate of acidogenesis may create more acids than can be converted by methanogenesis, affecting the stability of the process.[8] This problem could be overcome by using separate reactors. Yet the comparative disadvantage which single stage systems have in this regard can be overcome by co-digesting these more problematic wastes with other materials, biological reliability being improved by buffering and mixing. Hence, as Figure 6 shows, multi-step processes still account for only 10% or so of the market for OFMSW digesters.

Figure 6: Market Shares of Single-step and Multi-step Plants



Source: L. De Baere (2003) State of the Art Anaerobic Digestion of Municipal Solid Waste, paper presented at Sardinia Landfill Symposium, 2003.

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8 O. Bernal, P. Llabres, F. Cecchi and J. Mata-Alvarez (1992) A Comparative Study of the Thermophilic Biomethanization of Putrescible Organic Wastes, *Odpadny vody / Wastewaters,* Vol. 1, No.1, pp.197-206.

3.1.2.4 Continuous or Batch?

Most systems are continuous systems. Batch systems are usually simply filled with fresh wastes (with or without seed material) and are allowed to go through all stages of degradation in the dry phase. Sometimes described as being akin to 'landfill in a box', these systems generate much more biogas than landfills because of the continuous recirculation of leachate (effecting a partial mixing through distribution of inoculant, nutrients and acids) and the higher temperature of operation.

3.1.3 Post-treatment Processes

After digestion, if the feedstock is wet, the material may be spread directly to land (especially where co-digestion with other wastes has occurred). Usually, this requires licensing as digestate is often considered as a "sludge". Sometimes (e.g., in Denmark) it is considered as a product and can thus be applied onto farmlands with no licensing procedure.

Alternatively, solid and liquid fractions can be separated in which case, after two to four weeks' maturation (sometimes longer depending upon the application), a fully stabilised compost will have been developed from the solid fraction. This may have to be mixed with bulking material to ensure aerobic conditions. The liquid fraction may either be recycled for dilution of fresh waste, applied to land as a liquid fertiliser (again, frequently under licensing), or sent to a wastewater treatment plant (often following some separation of solids).

3.2 Key Factors in Considering Digestion Processes

According to Vandevivere at al, the three most important indicators of biological performance are:

- the rate of reaction;
- the degree of completion; and
- the stability of the biochemical reactions.[9]

The degree of completion is effectively the degree to which the biogas yield obtained in a reactor per unit of feed matches the maximum biogas yield obtainable in laboratory reactors operated under optimal conditions.

Many publications quote only the biogas yield, or alternatively the % removal of volatile solids (VS) from the waste stream to assess the degree of completion of the methanization process.[10] Biogas yield on its own, however, is of little use since it is more dependent on waste composition than on process performance. By way of illustration, a study by Saint Joly et al showed how the methane yield from a single plant varied between 170 and 320 Nm^3 CH_4/kg VS fed (40% and 75 % VS reduction) between the summer and winter months, respectively, as a result of the higher proportion of garden waste during

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[9] P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) *Biomethanization of the Organic Fraction of Municipal Solid Waste*, London: IWA Publishing, pp.111-140.

[10] The volatile solids (VS) in organic wastes are measured as total solids minus the ash content, as obtained by complete combustion of the feed wastes. The volatile solids comprise a biodegradable volatile solids (BVS) fraction and a refractory volatile solids (RVS) fraction. Kayhanian showed that knowledge of the BVS fraction of MSW helps in better estimation of the biodegradability of waste, of biogas generation, organic loading rate and C/N ratio (M. Kayhanian (1995) Biodegradability of the organic fraction of municipal solid waste in a high solids anaerobic digester, *Waste Management & Research* Vol.13, pp.123-136). Lignin is a complex organic material that is not easily degraded by anaerobic bacteria and constitutes the refractory volatile solids (RVS) in organic MSW. Waste characterized by high VS and low non-biodegradable matter, or RVS, is best suited to AD treatment. The composition of wastes affects both the yield and biogas quality as well as the compost quality.

summer months.[11] Garden wastes are known to yield much less biogas, relative to kitchen wastes, due to the higher proportion of poorly degradable lignocellulosic fibres. Similarly, one study showed that using the same reactor configuration, a two-fold larger VS reduction was achieved using source-separated biowaste relative to mechanically-sorted OFMSW.[12] Such differences are not due to process performance but rather (perhaps obviously) to the smaller biogas production potential of the mechanically-sorted OFMSW which contains a greater proportion of poorly degradable organic material such as plastic impurities.

A more useful criterion of biological performance is the maximum sustainable reaction rate, which can be expressed either as the rate of substrate addition, i.e. the maximum organic loading rate OLR_{max} (expressed in kg VS/m^3 reactor/day), or as a rate of product formation, i.e. the volume of dry biogas or, better still, that of methane (under standard conditions of pressure and temperature) produced per unit time per unit reactor volume (Nm^3 CH_4/m^3 reactor/day). These indicators are more useful than the biogas yield or % VS reduction because they are less affected by the composition of the waste and better reflect the level of biological activity that a given reactor design may sustain. In short, this enables a comparison of different reactor designs whereas comparative performance assessed through measures such as biogas yield is confounded by issues such as waste composition unless these are clearly controlled for (by using materials of the same composition).

Another parameter often used to quantify the rate of the process is the retention time, which is roughly the inverse of the OLR when the OLR is expressed as mass wet substrate instead of mass substrate VS. A high OLR suggests material resides for a shorter time in the reactor. This parameter does not give much biological information because it is too dependent on the relative solids content, and also, the level of dilution with process water. The required retention time for completion of the AD reactions varies with differing technologies, process temperature, and waste composition. The retention time for wastes treated in mesophilic digesters tends to range from 10 to 40 days. Lower retention times are possible in digesters operated in the thermophilic range. A high solids reactor operating in the thermophilic range may have a retention time of 14 days.

Probably, the only accurate way to present a 'true picture' of biological performance is to use all three indicators simultaneously, each of which conveys some information of relevance. The OLR_{max} indicates the degradative capacity of the system, and the biogas yield its conversion efficiency, with 100 % conversion efficiency being defined as the maximum biogas yield potential determined under optimal conditions in the laboratory. If the latter is unknown, the biogas yield remains a valid indicator only for comparisons between studies where wastes of similar origin and composition are used. Only those data pertaining to reactors where stable performance is demonstrated should be considered as reliable for obvious reasons.

3.2.1 Carbon : Nitrogen Ratio (C/N)

The relationship between the amount of carbon and nitrogen present in organic materials is represented by the C/N ratio. Optimum C/N ratios in anaerobic digesters are between 20 – 30. A high C/N ratio leads to rapid consumption of nitrogen by methanogens and results in lower gas production (because of a lack of nutrients). On the other hand, a lower C/N ratio leads to accumulation of ammonia and pH values which are toxic to methanogenic bacteria. Optimum C/N ratios of the digester materials can be achieved by mixing materials of high and low C/N ratios, such as organic solid waste mixed with sewage or animal manure.

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[11] C. Saint-Joly, S. Desbois and J-P. Lotti (2000) Determinant Impact of Waste Collection and Composition on Anaerobic Digestion Performance: Industrial Results, *Water Science and Technology*, Vol.41, No.3, pp. 291-7.

[12] Pavan, P., Battistoni, P., Mata-Alvarez, J. (1999) Performance of thermophilic semi-dry anaerobic digestion process changing the feed biodegradability. In *II International Symposium on Anaerobic Digestion of Solid Waste*, Barcelona, June 15-17, 1999, pp. 57-64.

3.2.2 pH Level

Anaerobic bacteria, specially the methanogens, are sensitive to the acid concentration within the digester and their growth can be inhibited by acidic conditions. Optimum pH values for AD lie between 5.5 and 8.5. During digestion, the two processes of acidification and methanogenesis require different pH levels for optimal process control. The retention time of digestate affects the pH value and in a batch reactor acetogenesis occurs at a rapid pace. Acetogenesis can lead to accumulation of large amounts of organic acids resulting in the pH falling below 5.

Excessive generation of acid can inhibit methanogens, due to their sensitivity to acid conditions. Reduction in pH can be controlled by the addition of lime or recycled filtrate obtained during residue treatment. Indeed, the use of recycled filtrate can even eliminate the lime requirement. As digestion reaches the methanogenesis stage, the concentration of ammonia increases and the pH level can exceed 8. Once methane production is stabilized, the pH level tends to stay between 7.2 and 8.2.

3.2.3 Mixing

The purpose of mixing in a digester is to blend the fresh material with digestate containing microbes. Furthermore, mixing prevents scum formation and avoids temperature gradients within the digester. However excessive mixing can disrupt the microbes so slow mixing is preferred. The kind of mixing equipment and amount of mixing varies with the type of reactor and the solids content in the digester.

3.3 Potential Benefits of Co-digestion

The effects of co-digestion on the feedstock and its different characteristics is shown in Table 2 and Table 3 for the cases where the organic fraction of municipal waste is mixed with livestock manures and sewage sludge.

In the case of livestock wastes, the Danish situation is one in which a number of plants co-digest some SOFMSW with livestock wastes (and industrial organic wastes). Livestock wastes have a good bufferng capacity because of their ammonia content, and as far as dilution of drier feedstocks are concerned, it has the positive attribute of being usually only 3-5% solids in the case of pig slurry, and 6-9% solids in the case of wastes from cattle and dairy cows. Its nutrient content is relatively high, however, so it aids bacterial growth. If livestock wastes are used on their own, the methane yield is relatively low. This is because of the low solids content and the high proportion of solids which contain lignocellulose. The addition of industrial organic wastes, or SOFMSW, can increase the biogas potential of a plant.

Table 2: Characteristics of Organic fractions of Municipal Solid Waste and Livestock Waste

Characteristic	SOFMSW	Livestock Waste
Content of Macro- and Micronutrients	Low	High
C:N Ratio	High	Low
Buffer capacity	Low	High
Content of biodegradable organic matter	High	Low
Dry matter content	High	Low

Source: Adapted from H. Hartmann, I. Angelidaki and B. K. Ahring (2003) Co-digestion of the Organic Fraction of Municipal Waste with Other Waste Types, in J. Mata-Alvarez (ed) (2003) Biomethanization of the Organic Fraction of Municipal Solid Waste, London: IWA Publishing, pp.181-99.

Similar comments can be made with respect to sewage sludge. However, whilst the Table suggests a beneficial co-digestion owing to the complementary characteristics of waste streams, the end use of the resulting digestate may be compromised by the higher level of contamination of sludge with heavy metals and with organic pollutants. Hence, unless digestion processes are able to manage the presence of these contaminants, it may be better to restrict co-digestion of sewage sludge to situations where only organic waste extracted from residual waste is co-digested in this way. Alternatively, smaller quantities of sewage sludge could be used. With regard to the latter, some dry digestion systems have experimented with the use of sludge to provide higher nutrient content so as to stimulate microbial growth.

Table 3: Characteristics of Organic fractions of Municipal Solid Waste and Sewage Sludge

Characteristic	OFMSW	Sewage Sludge
Content of Macro- and Micronutrients	Low	High
C:N Ratio	High	Low
Content of biodegradable organic matter	High	Low
Dry matter content	High	Low

Source: Adapted from H. Hartmann, I. Angelidaki and B. K. Ahring (2003) Co-digestion of the Organic Fraction of Municipal Waste with Other Waste Types, in J. Mata-Alvarez (ed) (2003) Biomethanization of the Organic Fraction of Municipal Solid Waste, London: IWA Publishing, pp.181-99.

3.4 Summary

This brief summary introduces some of the basics of digestion processes. In the following Section, the specifics of certain reactor types are examined in more detail, alongside a review of what technologies and suppliers are available.

4.0 REVIEW OF ESTABLISHED AND EMERGING AD TECHNOLOGIES

The approach to classifying anaerobic digestion technologies is likely to depend upon one's perspective. Biologists will be concerned with the rate, stability and degree of completion of biochemical reactions, whilst engineers will be interested in wear and maintenance of physical and electro-mechanical devices. Equally, environmentalists will focus on emissions, and the inputs and outputs of the project, whilst buyers and sellers will focus on the capital outlays and the operational expenditure required.

In the light of discussion from the previous section, we approach the issue broadly in line with the view taken by Vandevivere et al.[13] We concentrate on systems designed to treat, in the main, either SOFMSW, or OFMSW.

4.1 One Stage Systems

As described in the previous section, In one-stage systems, all these reactions take place simultaneously in a single reactor, while in two- or multi-stage systems, the reactions take place sequentially in at least two reactors. For most feedstocks, performance of one-stage systems is equivalent to two-stage systems.

4.1.1 Wet, Complete Mix Systems

In essence, this technology, sometimes called a CSTR (continuously stirred tank reactor), mirrors that which has been used for treating biosolids. The material is made to resemble biosolids by pulping, slurrying and mixing with water (so that a feedstock of less than 15% solids is obtained). The slurry is then digested in large complete mix reactors in which solids are kept in suspension by vertical impellers.

The apparent simplicity of design masks some of the difficulties in managing the process properly. Pre-treatment to ensure the desired consistency and purity of feedstock is not straightforward, though it is more so for SOFMSW. The removal of contraries inevitably implies a concurrent loss of volatile solids with subsequent loss in gas yields.

Furthermore, the mass tends to separate out into layers in accordance with relative densities. 'Heavies' tend to sink, and may damage the propellers, whilst the floating layer may hamper mixing. Periodic extraction of these is necessary to improve reliability. Because some heavies may do damage to pumps, the best solution is to ensure, as far as possible, their removal prior to their reaching the reactor.

Some concerns also arise in respect of the possibility for short-circuiting. If some solids are not treated for an especially long time, sanitization (i.e. the level of pathogen kill) may be less than complete. Detailed designs have sought to overcome this (through the construction of pre-chambers etc., as in the WAASA process) but even so, the perceived inadequacy of such measures may still make it necessary to pasteurize wastes prior to digestion. This may be done by, for example, injecting steam into the pulper to maintain a temperature of 70°C or so.

Several interesting designs have been used to try to ensure adequate mixing of the material. Some have tried to overcome the need to have moving parts within what is a sealed reactor. For example the Linde process uses a loop reactor design where an ascending movement in a central compartment is created by

[13] P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) *Biomethanization of the Organic Fraction of Municipal Solid Waste*, London: IWA Publishing, pp.111-140.

injection of recirculated biogas at the bottom end of a central tube. Mixing modes using a combination of propellers and gas recirculation are also sometimes used.

A drawback of wet systems is the large amount of water used, resulting in high reactor volume and expensive post-treatment due to the dewatering required at the end of the digestion process. Examples of wet single-step systems for treating biowastes are the WAASA process in Finland and the EcoTec systems in Germany. In the UK, the Greenfinch process is also a wet single-step process.

4.1.2 Dry Systems

Research during the 1980s demonstrated that biogas yield and production rate were at least as high in wet systems, in systems where the wastes were kept in their original solid state, i.e. not diluted with water.[14] In dry systems, different challenges present themselves. The key one, perhaps, is that of handling, pumping and mixing solid streams.

In dry systems, the material within the reactor is kept at a solids content in the range 20 - 40 % TS, so that only very dry substrates (> 50 % TS) need be diluted with process water. Transport and handling of the wastes is with conveyor belts, screws, and powerful pumps especially designed for highly viscous streams. This type of equipment is more expensive than the centrifugal pumps used in wet systems but it is also more robust and flexible inasmuch as wastes with solids content anywhere between 20 and 50 % can be handled. In such systems, at least in the process of digestion itself, impurities such as stones, glass or wood do not pose problems. The principle pre-treatment necessary is the removal of the coarse impurities larger than 40 mm. This can be accomplished either via screens, as is typically the case with mechanically-sorted OFMSW, or via shredders in the case of source-separated biowaste. Any heavy inert materials which pass the pre-treatment need not be removed. This makes the pre-treatment of dry systems somewhat simpler than that of their wet counterparts, and probably more attractive for the biomethanization of OFMSW, which typically contain 25 % by weight of heavy inerts.

On the other hand, though SOFMSW is treated successfully in dry systems, some suggest that where the quality of source separation is less good, then in terms of generating a high quality end-product for application to land, wet systems may offer more straightforward approaches to improving the quality of the feedstock input to the digester (and might also offer more possibilities for wet separation following the process). Hence, it may be that in dense urban areas, where the accuracy of separation is not always so high, or where collection systems are not so convenient, or where they are 'open access' in nature, wet systems might be favoured in respect of their being more likely to generate quality digestates.

Due to their high viscosity, in dry reactors, wastes move via plug flow. This offers the advantage of technical simplicity since no mechanical devices need to be installed within the reactor but the mixing of the incoming wastes with the fermenting mass, which is crucial to guarantee adequate inoculation and to prevent local overloading and acidification, becomes problematic.

The three best-known designs for the effective mixing of solid wastes at the industrial scale are the Dranco, Kompogas , and Valorga systems. Each of these operates in the thermophilic range, though some Valorga systems operate in the mesophilic range. In the Dranco process, the feedstock is introduced at the top and digested matter, extracted from the bottom, is mixed with incoming fresh

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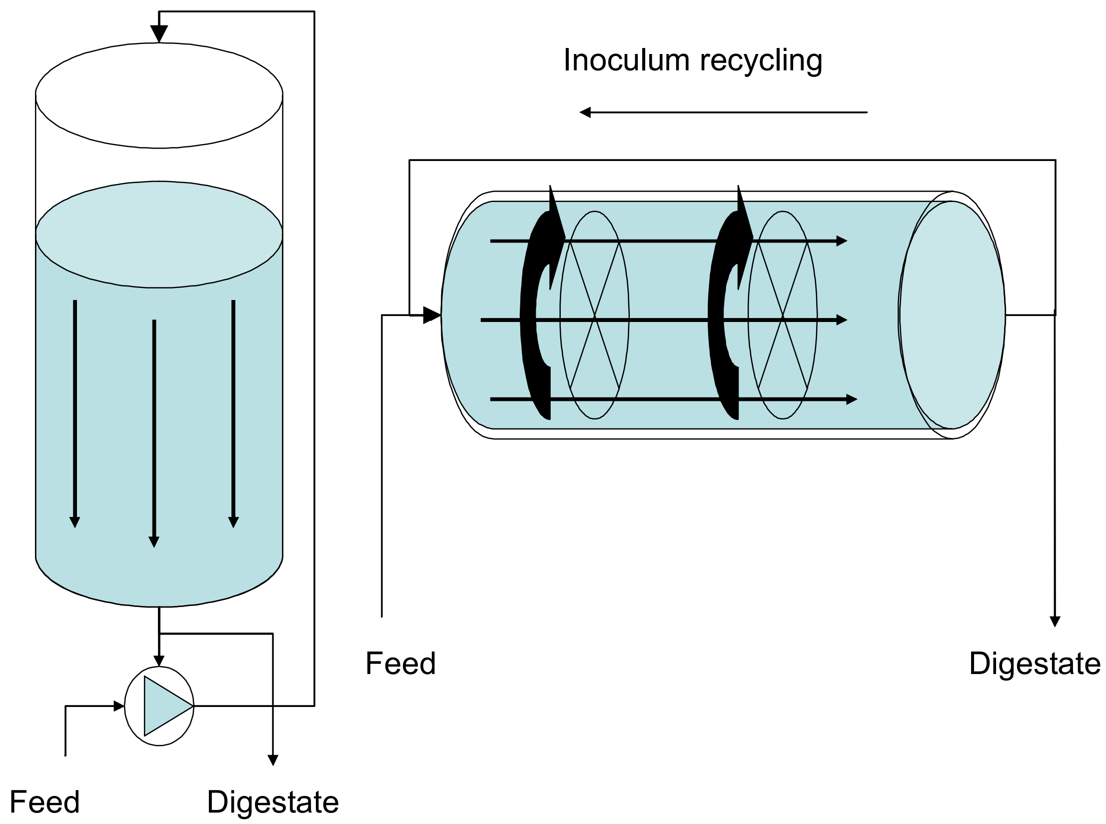
[14] H.-H. Spendlin and R. Stegmann (1988) Anaerobic Fermentation of the Vegetable, Fruit and Yard Waste; in *Proceedings of the 5th International Solid Wastes Conference*, Copenhagen. Sep.11-16, 1988, London: Academic Press, p.25-31; D. Baeten and W. Verstraete (1993) In-reactor Anaerobic Digestion of MSW Organics, in H. A. J. Hoitink and H. M. Keener (ed.) *Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects*, Worthington, OH: Renaissance Publications, pp.111-29; J. A. Oleszkiewicz and Poggi-Varaldo (1997) High-solids Anaerobic Digestion of Mixed Municipal and Industrial Wastes, *Journal of Environmental Engineering*, Vol.123, pp.1087-92.

wastes in the ratio one part fresh wastes to six parts digested wastes. This simple design has been shown effective for the treatment of wastes ranging from 20 to 50 % TS.

The Kompogas process works in a similar manner except for the fact that the plug flow takes place horizontally in cylindrical reactors. Movement is aided by slowly-rotating propellers inside the reactors, which also agitate, and serve to homogenize, degas, and resuspend heavier particles. However, this system requires the solids content to be maintained at around 23 % TS – at lower values, heavy particles such as sand and glass tend to sink and accumulate inside the reactor while material with higher solids content create excessive resistance to the flow.

Figure 7: Diagrammatic Representation of Dranco (left) and Kompogas (right) Reactors



Source: Based upon P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) Biomethanization of the Organic Fraction of Municipal Solid Waste, London: IWA Publishing, pp.122.

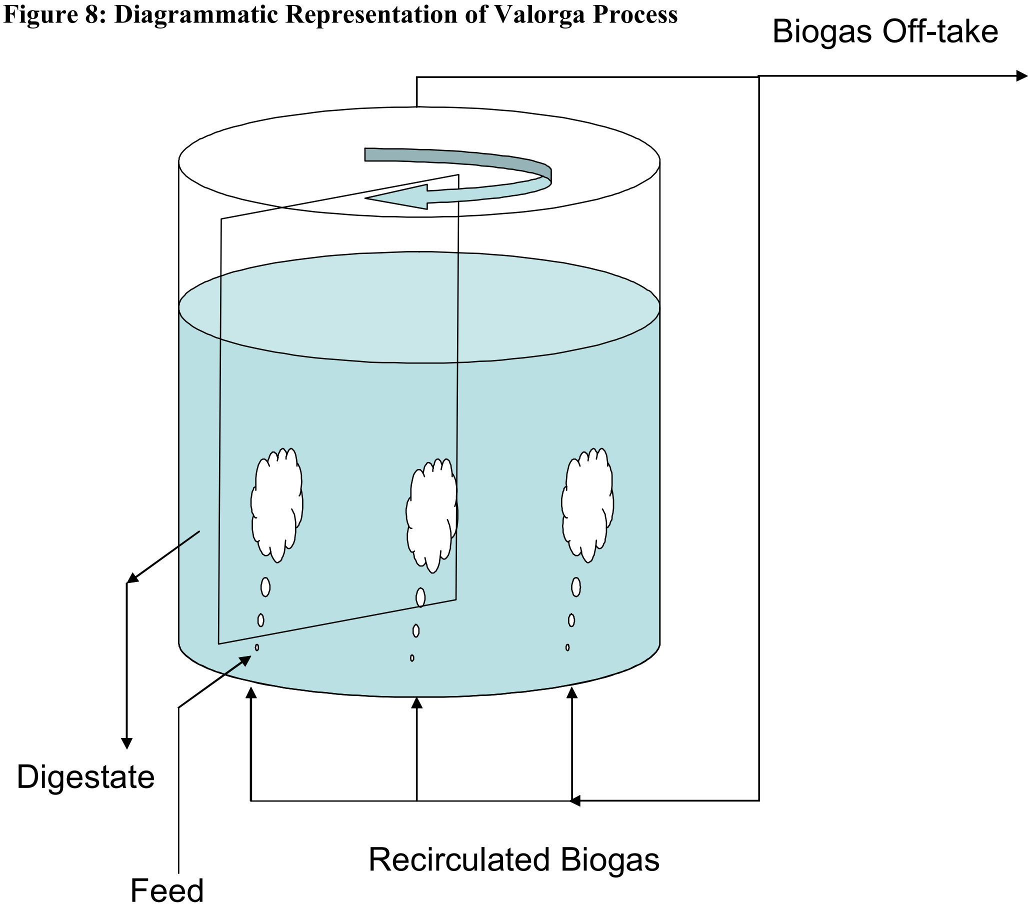
The Valorga system is unique in that the horizontal plug flow is circular in a cylindrical reactor and mixing occurs via biogas injection at high pressure at the bottom of the reactor every 15 minutes through a network of injectors.[15] The digested wastes leaving the reactor are not recirculated. A technical drawback of this design is that gas injection ports can become clogged and maintenance of these is cumbersome. As in the Kompogas process, process water is recirculated in order to achieve a desired solids content, in this case of 30 % TS, inside the reactor. The Valorga design is ill-suited for relatively

[15] H. Fruteau de Laclos, S. Desbois and C. Saint-Joly (1997) Anaerobic Digestion of Municipal Solid Organic Waste: Valorga Full-scale Plant in Tilburg, The Netherlands, in *Proceedings of the 8th International Conference on Anaerobic Digestion*, Sendai, May 25-29 1997, Vol.2, pp.232-238.

wet wastes since sedimentation of heavy particles inside the reactor takes place if the solids content falls beneath 20 % TS.

Due to mechanical constraints, the volume of the Kompogas reactor is fixed and the capacity of the plant is adjusted by building several reactors in parallel, each one with a treatment capacity of either 15,000 or 25,000 ton/yr.[16] On the other hand, the volume of the Dranco and Valorga reactors can be sized for the capacity required, though they are not made to exceed 3,300 m^3 and a height of 25 m.

Figure 8: Diagrammatic Representation of Valorga Process



Source: Based upon P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) Biomethanization of the Organic Fraction of Municipal Solid Waste, London: IWA Publishing, pp.122.

Dry systems have gained in popularity over time. No clear technology trend can be observed at this moment. Vandevivere et al suggest much will depend on the success of wet systems in dealing with mechanically-sorted OFMSW. 'Dry' systems have already proven reliable in this respect in France and Germany.[17] However, future legislation and standards regarding residues is also likely to be influential.

[16] F. Thurm and W. Schmid (1999) Renewable Energy by Fermentation of Organic Waste with the Kompogas Process, in *II International Symposium on Anaerobic Digestion of Solid Waste*, Barcelona, June 15-17, 1999, pp. 342-355.

[17] P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) *Biomethanization of the Organic Fraction of Municipal Solid Waste*, London: IWA Publishing, pp.111-140.

4.2 Two Stage Systems

As discussed in the previous section, the rationale for two-stage systems is to optimize the rates of different reactions in the digestion process. Two-stage systems are found with and without a biomass retention scheme in the second stage. The retention of biomass within a reactor is an important variable in determining the biological stability of the digester. Unstable performance can be caused either by fluctuations in the OLR, due to changing waste composition or discontinuous feeding, or by wastes excessively charged with inhibiting substances such as nitrogen.

All types of two-stage systems, regardless of whether biomass is accumulated or not, provide some buffering against the fluctuations of OLR. However, only those two-stage systems with biomass retention schemes display stable performance with wastes excessively charged with nitrogen or other potential inhibitors. Most commercial two-stage designs propose a biomass retention scheme in the second stage.

4.2.1 Without Biomass Retention

The most simple design of two-stage systems, used primarily in laboratory investigations, are two complete mix reactors in series. The technical features of each reactor are comparable to those presented above for the one-stage 'wet' system. Another possible design is the combination in series of two plug-flow reactors, either in the 'wet-wet' or 'dry-dry' mode, as illustrated by the Schwarting-Uhde and BRV processes, respectively.

In the Schwarting-Uhde process, the source-separated biowaste, finely chopped and diluted to 12 % TS, rises upward through a series of perforated plates placed within the reactors. Uniform upward movement is imparted by pulsating pumps which also ensure localized short- term mixing via time-controlled impulses creating rapid rising of the liquid column. The impulses also push the biogas through the plate apertures. This elegant design, applied under 'wet' thermophilic conditions, is able to ensure, without any internal moving parts, adequate mixing and a plug flow mode which guarantees complete hygienization since short-circuiting is avoided. Moreover this design is not conducive to the formation of the thick floating scum layer commonly plaguing wet reactors. Its sensitivity to clogging of the perforated plates, however, limits the Schwarting-Uhde process to relatively clean highly biodegradable biowastes.

In the BRV process, the source-separated biowastes, adjusted to 34 % TS, pass through an aerobic upstream stage where organics are partially hydrolyzed and around 2 % lost through respiration. The reason for conducting the hydrolysis stage under microaerophilic conditions is that the loss of COD due to respiration is more than compensated by a higher extent of liquefaction, which, moreover, proceeds faster than under anaerobic conditions. After a two-day retention time, the pre-digested wastes are pumped through methanogenic reactors in a horizontal plug flow mode. The digestion lasts 25 days at 55 °C and 22 % TS. The primary advantages of this system are the use of 'dry' conditions which reduces the size of the digesters, and the use of piston flow which affords complete hygienization without a pasteurization step. The horizontal flow requires however the use of floor scrapers to eliminate the heavy material from the reactor and mixing equipment inside the reactor to prevent the formation of a crust layer.

4.2.2 With a Biomass Retention Scheme

In order to increase rates and resistance to shock loads or inhibiting substances, it is desirable to achieve high densities of the slowly-growing methanogenic micro-organisms in the second stage. There are two basic ways to achieve this:

1. The first method to increase the concentration of methanogens in the second stage is to uncouple the hydraulic and solids retention time, thereby raising the solid content in the methanogenic reactor. These accumulated solids represent active biomass only in the case of wastes leaving no

more than 5-15 % of their original solid content as residual suspended solids inside the reactor. This design will therefore be effective only for highly hydrolyzable kitchen or market wastes;

2. The second way is to design the second stage with support material allowing attached growth, high cell densities and long sludge age. The prerequisite for this design is that the feed to the attached growth reactor contains few suspended particles, which means that the suspended solids remaining after the hydrolysis (first) stage should be removed. Two industrial processes, the BTA and Biopercolat designs, are based on these principles. Both of these are currently used to treat OFMSW as part of mechanical biological treatment (MBT) configurations.

In the BTA 'wet-wet' process, the 10 % TS pulp exiting the pasteurization step is dewatered and the liquor directly sent to the methanogenic reactor. The solid cake is resuspended in process water and hydrolyzed in a complete mix reactor under mesophilic conditions (HRT 2-3 d). The pH within the hydrolysis reactor is maintained in the range 6-7 by recirculating process water from the methanogenic reactor. From a technical point of view, this design shares the same limitations as the one-stage 'wet' system, i.e. short-circuiting, foaming, sinking of heavies, fouling of the impeller blades with plastic foils, obstruction of pipes with long objects such as sticks, and loss of 10-30 % of the incoming VS caused by the removal of the rake fraction in the hydropulper. The major drawback of the 'wet-wet' system remains however its technical complexity as four reactors are necessary to achieve what other systems achieve in a single reactor.

The Biopercolat follows the same principles as the BTA process, with the difference that the first stage is carried out under 'dry' and microaerophilic conditions and is continuously percolated with process water to accelerate the liquefaction reaction. The Biopercolat system is quite innovative from a technical point of view. In order to prevent the channelling and clogging typically occurring in 'dry' percolated systems, percolation occurs in large slowly-rotating (1 rpm) sieve drums with 1 mm mesh openings. The 'dry' design of the percolation hydrolysis stage avoids the troublesome pulping stage required in 'wet' or 'wet-wet' systems. This system is, however, relatively new with the first full-scale plant only recently having started operating in Germany.

4.3 Batch Systems

Batch systems have not succeeded in taking a substantial market share of the digestion market. However the specific features of batch processes, such as a simple design and process control, robustness towards coarse and heavy contaminants, and lower investment cost make them particularly attractive for developing countries, for example.

Three basic batch designs may be recognized, which differ in the respective locations of the acidification and methanogenesis phases.

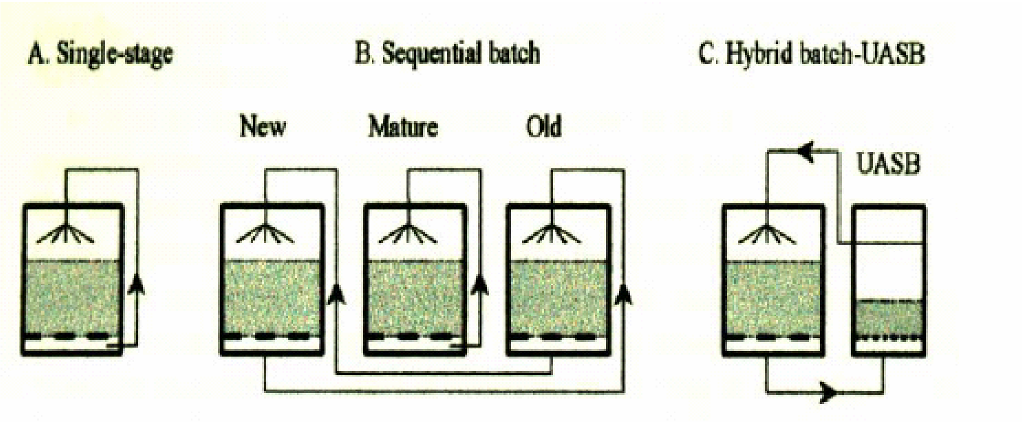
1. In the **single-stage batch** design, the leachate is recirculated to the top of the same reactor where it is produced. This is the principle of the Biocel process, which is implemented in a full-scale plant in Lelystad, The Netherlands. The waste is loaded with a shovel in fourteen concrete reactors, each of 480 m^3 effective capacity and run in parallel. The leachates, collected in chambers under the reactors, are sprayed on the top surface of the fermenting wastes. One technical shortcoming of this and other batch systems, is the plugging of the perforated floor, resulting in the blockage of the leaching process. This problem is alleviated by limiting the total mass of the fermenting wastes in order to limit compaction and by mixing the fresh wastes with bulking material (one tonne dewatered digested wastes and 0.1 tonne wood chips added per tonne fresh wastes). The addition of dewatered digested wastes, aside from acting as bulking material, also serves the purpose of inoculation and dilution of the fresh wastes. Safety measures need to be closely observed during the opening and emptying of the batches, as explosive conditions can occur.

2. In the **sequential batch** design, the leachate of a freshly-filled reactor, containing high levels of organic acids, is recirculated to another more mature reactor where methanogenesis takes place. The leachate of the latter reactor, freed of acids and loaded with pH buffering bicarbonates, is pumped back to the new reactor. This configuration also ensures cross-inoculation between new and mature reactors which eliminates the need to mix the fresh wastes with seed material. The technical features of the sequential batch design are similar to those of the single-stage design.

3. Finally, in the **hybrid batch-UASB** design, the mature reactor where the bulk of the methanogenesis takes place is replaced by an upflow anaerobic sludge blanket (UASB) reactor. The UASB reactor, wherein anaerobic microflora accumulates as granules, is well suited to treat liquid effluents with high levels of organic acids at high loading rates. This design is very similar to the two-stage systems with biomass retention such as the Biopercolat system discussed above, with the difference that the first stage is a simple fill-and-draw (batch) rather than a fully mixed reactor.

The three types are illustrated diagrammatically in Figure 9.

Figure 9: Diagrammatic Representation of Different Batch Reactors



Source; P. Vandevivere, L. De Baere and W. Verstraete (2003) Types of Anaerobic Digester for Solid Wastes, in J. Mata-Alvarez (ed) Biomethanization of the Organic Fraction of Municipal Solid Waste, London: IWA Publishing, pp.111-140.

4.4 Comment on Design Types

An assessment of pros and cons of different system types is shown in Table 4. In the last 25 years, a considerable shift in attitude towards in-reactor digestion of solid wastes has occurred. Scepticism has been replaced by general acceptance that various digester types are functioning at industrial scale in a reliable manner. This is illustrated by the growth in installed capacity over recent years (see Figure 10).

Most existing full-scale plants were designed with a single-stage reactor and reflect the relative newness of the technology. De Baere's view is that one-stage systems will continue to dominate the market, but that the reactor designs will be improved and matched to more specific substrates. This should provide far more reliable plants.

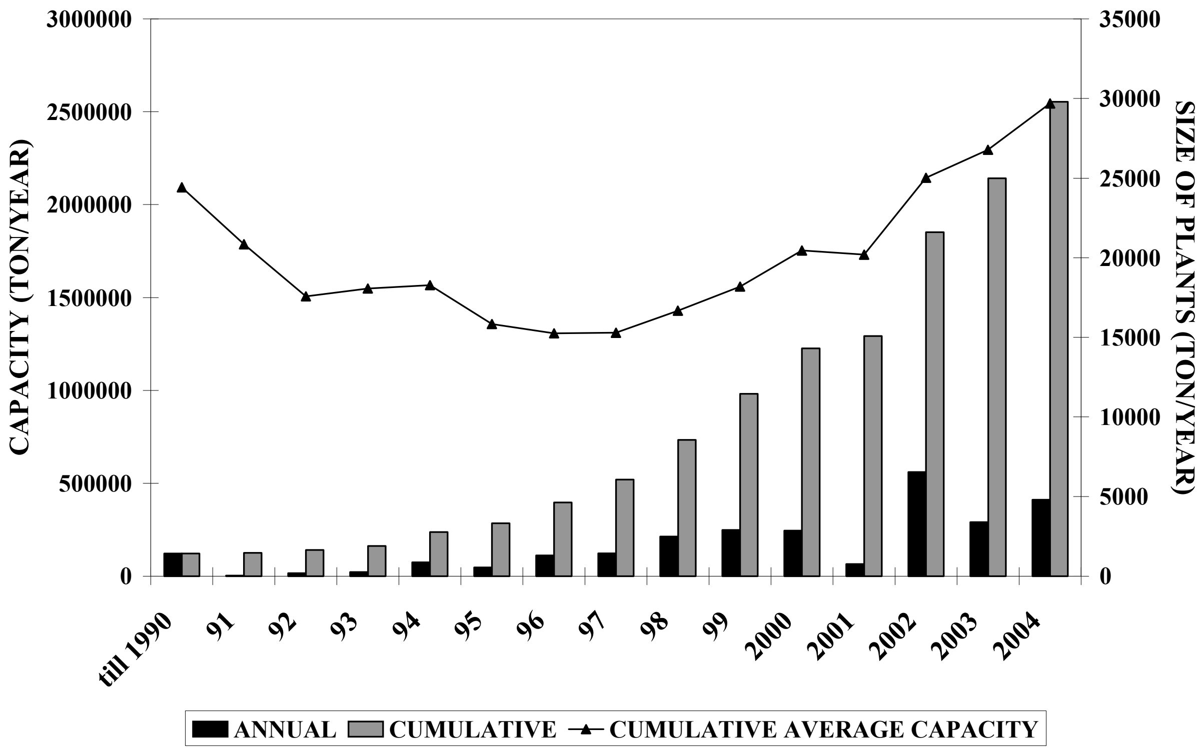
Table 4: Advantages and Disadvantages of Different Systems

Criteria	Advantages	Disadvantages
Wet Single Step		
Technical	Inspired from known process	Short-circuiting Sink and float phases Abrasion with sand / grit Complicated pre-treatment
Environmental	Dilution of inhibitors with fresh water	Particularly sensitive to shock loads as inhibitors spread immediately in reactor Where pre-sorting is required, VS lost with inerts and / or plastics
Economic and Environmental	Equipment to handle slurries is cheaper	High consumption of water Additional pre-treatment steps Larger reactor volume (because of dilution) High energy requirement for heating large volume
Dry Single Step		
Technical	No moving parts inside reactor (Maintenance less awkward) Robust (inerts and plastics need not be removed) No-short-circuiting	Wet wastes (<20% TS) cannot be treated alone
Environmental	Low VS loss in pre-treatment Lrger OLR (high biomass) Limited dispersion of transient peak concentrations of inhibitors (these are constrained)	Little possibility to dilute inhibitors
Economic and Environmental	Cheaper pre-treatment and smaller reactors Complete hygienisation Low water usage Low heat requirement (no water to heat up)	Though more robust, equipment is more expensive
Two Step Processes		
Technical	Design flexibility	
Environmental	More reliable for cellulose poor kitchen wastes Only reliable design (with biomass retention) for wastes with C:N ratios < 20	Smaller biogas yields (when solids not methanogenized)
Economic and Environmental	Less heavy metal in compost (when solids not methanogenized)	Larger investment
Batch Systems		
Technical	Simple Low-tech Robust (inerts, plastics need not be removed)	Clogging Need for bulking agent Risk of explosion during emptying of reactor
Environmental	Reliable process due to niches and use of several reactors	Poor biogas yield due to channelling of percolate Small OLR
Economic and Environmental	Cheap Low water consumption	Large land requirement (similar to aerobic processes)

Many companies are now offering several versions of one technology, or propose both 'wet' and 'dry' systems. Two-stage systems may start to play a more important role if treatment of industrial wastes is to be combined with that of biowaste, and hygienization may require a separate treatment step at higher temperatures. Batch systems have not been especially popular. This may be due to the fact that concerns in respect of hygienization and safety requirements make these systems more difficult to introduce. Batch systems could be more applicable in developing countries due to the low investment costs.

At present, and most likely, this will remain the case in the future, it is not possible to single out specific processes as all-round 'best performers' and optimally suited under all circumstances. Many variables have to be taken into consideration and a final evaluation for a specific site will need to be made. There is and will continue to be room for technical diversity in this domain of waste treatment. For this reason, any feasibility study which seeks to recommend specific technologies is likely to be confronted with significant difficulties in the absence of a clear specification of the situation being addressed, including everything from the collection system used through to the materials available for co-digestion, and including the most practical treatment, which might, in turn, be affected by the desired end-product.

Figure 10: Annual and Cumulative Capacity of AD Plants Treating Municipal Wastes



Source: L. De Baere (2003) State of the Art Anaerobic Digestion of Municipal Solid Waste, paper presented at Sardinia Landfill Symposium, 2003.

4.5 Operating Commercial Plants

Even if attention is restricted to industrial scale facilities, there are around 50 providers of AD technology active at present (see Table 5). A list of operating plants was given in the IEA report 'Biogas and More', though this is now out-of-date and incomplete. At least 28 plants have been commissioned since 2001, some of which have been added to the Table by ourselves. However, the Table, reproduced as Table 6, gives an idea of the spread of plants, and their typical size. Recent years have seen notable investments in, for example, Spain. Spain now has more capacity installed per million inhabitants than any other country. It also shows that AD plants treating fractions of municipal waste (source separated, and residual) can be found in many countries. An interesting point is that interest in AD has grown not only for source separated biowastes, but also for mixed municipal wastes. This is further evidence of increased confidence in the technology to treat solid fractions.

It is also clear from Table 6 that AD plants which treat either SOFMSW or OFMSW frequently treat other wastes as well. The most common wastes are agricultural waste and organic industrial wastes (OIW), but co-digestion with biosolids (sewage sludge) is also to be found.

Some UK based companies are to be found in the list of suppliers. These include Practically Green (based in Northern Ireland), Greenfinch, Portagester, and Organic Power.

Table 5: Suppliers of AD Technology

Company	Company
AAT Gmbh & Co	Kompogas AG
NNR (Nellerman Neisel & Rauschenberger)	Komptech-Farwick
ANM	Krieg & Fischer Gmbh
Arge Biogas	Kruger Ltd
Atlas Group pty Ltd.	Linde KCA Dresden Gmbh
Bioplan	Niras Ltd
Bioscan	Organic Power
Biotechnische Abfallverwertung Gmbh & Co KG (BTA)	Organic Waste Systems
Burmeister & Wain Scandinavian (BWSC) Ltd	Paques
Citec	Passavant Roediger
DEES	Portagester
DSD	Practically Green
Entec	Purac
Enviro-Control	rom-OPUR
Eurec Technology Gmbh/CCP	RPA
Farmatic	Safe-Waste-Systems Ltd
GasCon Aps	Schwarting Umwelt
Greenfinch	SPI
Grontmij Water and Resstoffen Contracting bv	Ros Roca International
Haase Energietechnic	U-Plus / ISKA Gmbh
Heidemij Biocel	TBW / Biocomp
Herning Municipal	Thames Waste Management
Hese Umwelt	Valorga International SAS
IMK	WAASA
Ionics Italbia	Wabio
C. G. Jensen	Wehrle Werk AG
KIKlos	YIT / VMT

Source: Various Sources

Table 6: List of Operating AD Plants of Commercial Scale

COUNTRY / LOCATION	FEEDSTOCK	SYSTEM	SCALE tpa	DATE
Austria				
Bergheim-Siggerwiesen	MSW	Dranco	20000	1993
Böheimkirchen	Biowaste, Agricultural	Arge Biogas	5000	1996
Eferding	OIW	Entec	7500	1984
Feldbach	MSW	AAT	11,000	1998

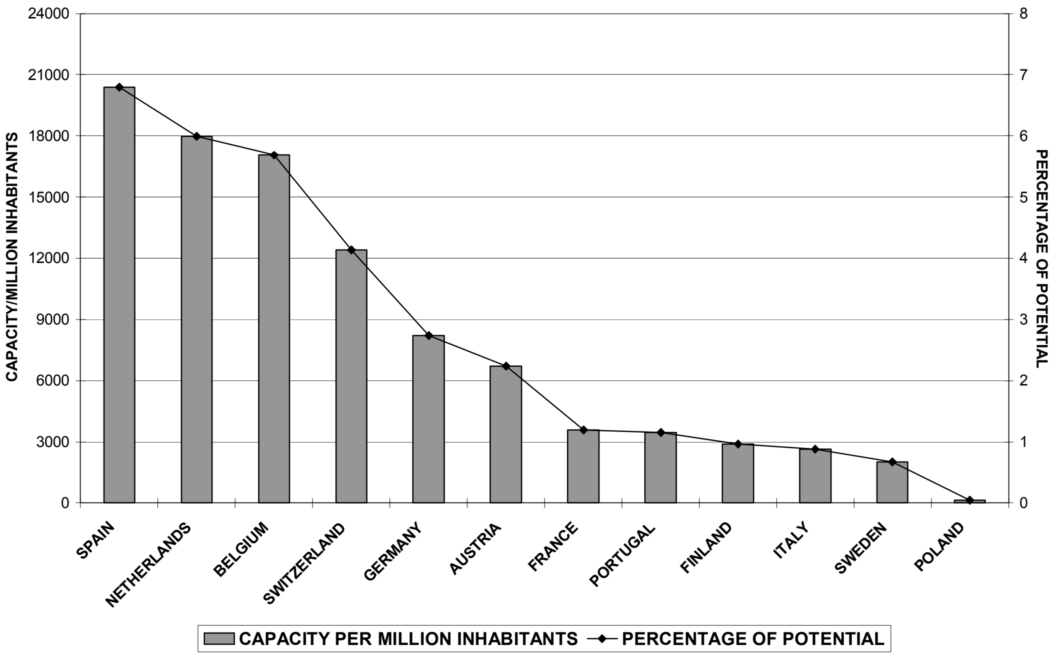
COUNTRY / LOCATION	FEEDSTOCK	SYSTEM	SCALE tpa	DATE
Frastanz	OIW	Entec	17000	1985
Graz	MSW	Dranco		1990
Hirsdorf	Agricultural, Biowaste, OIW	Entec		1994
Hollabrunn	OIW	Entec	11000	1983
Kainsdorf	Biowaste, Agricultural, OIW	Entec	14000	1995
Koblach	MSW	AAT	15000	1993
Leesternau	Biowaste	Kompogas	8000	1997
Lustenau	Biowaste	Kompogas	10000	1996
Mayerhofen	Biowaste, Agricultural	Arge Biogas	2500	1997
Roppen	Biowaste	Kompogas	10000	2001
Salzburg	OIW, Biosolids	AAT	160000	1999
Wels	Biowaste	LINDE	15000	1996
Westerwesede	Agricultural, OIW	Entec	5000	1986
Belgium				
Brecht	Biowaste	Dranco	20000	1992
Brecht	Biowaste	Dranco	50000	2000
Gent	MSW	AAT	182000	1999
Mons	35700 from source separation, balance general household	Valorga	58700	2001
Canada				
Newmarket, ON	Biowaste, OIW	BTA	150000	2000
Denmark				
Århus	Biowaste, Agricultural, OIW	C.G. Jensen	125000	1995
Blaabjerg	Agricultural, OIW	BWSC/Bioscan	113000	1996
Blåhøj	Agricultural, OIW	NIRAS	30000	1997
Davinde	Agricultural, OIW	Krüger	10000	1988
Fangel	Agricultural, OIW	Krüger	53000	1989
Filskov	Agricultural, OIW	NIRAS	27000	1995
Grindsted	Biowaste, Biosolids	Krüger	40000	1997
Hashøj	Agricultural, OIW	Krüger	53000	1994
Hodsager	Agricultural, OIW	NIRAS	17500	1993
Lemvig	Agricultural, OIW	BWSC	144000	1992
Lintrup	Agricultural, OIW	Krüger/Bioscan	190000	1990,
Nysted	Biowaste, Agricultural, OIW	Krüger	100000	1998
Revninge	Agricultural, OIW	Bioscan	15300	1989
Ribe	Agricultural, OIW	Krüger	147000	1990
Sinding	Biowaste, Agricultural, OIW	Herning Municipal	45000	1988
Snertinge	Agricultural, OIW	NIRAS	43000	1996
Studsgård	Biowaste, Agricultural, OIW	Herning Municipal	130000	1996
Thorsø	Agricultural, OIW	BWSC	110000	1994
Vaarst-Fjellerad	Biowaste, Agricultural, OIW	NIRAS	55000	1997
Vegger	Biowaste, Agricultural, OIW	Jysk Biogas	19000	1986
Vester Hjermitslev	Agricultural, OIW	Krüger	17000	1984
Finland				
Vaasa	MSW	Waasa/Wabio	15000	1994
France				
Amiens	MSW	Valorga	85000	1988
Varennes-Jarcy	30000 source sep HHW, balance mixed	Valorga	100000	2003
Germany				
Alzey-Worms	Biowaste	Kompogas	24000	2000
Baden-Baden	Biowaste, Biosolids	BTA	5000	1993
Bassum	MSW, Sludge	Dranco	13500	1997
Behringen	Agricultural, OIW	LINDE	23000	1996
Bottrop	Biowaste	Wabio	6500	1995
Braunschweig	Biowaste	Kompogas	20000	1997
Buchen	MSW	ISKA	20,000	2001
Dietrichsdorf-Volkenschwand	Biowaste, OIW	BTA	17000	1995
Ellert	Biowaste	Entec	5000	1997
Engelskirchen	Biowaste	Valorga	35000	1998
Erkheim	Biowaste, OIW	BTA	11,000	1997
Finsterwald	Biowaste, Agricultural	Schwarting UHDE	90000	1995
Frankfurt	Biowaste	Kompogas	15000	2000
Freiburg	Biowaste	Valorga	36000	1999
Fürstenwalde	Biowaste, OIW	LINDE	85000	1998
Ganderkesee	Biowaste	ANM	3000	1995
Gröden-Schraden	Agricultural, OIW	Haase Energietechnic	110000	1995
Groß Mühlingen	Biowaste, Agricultural, OIW	DSD	42000	1996
Groß Pankow	Agricultural, OIW	Alusteel/NNR	7700	1994

COUNTRY / LOCATION	FEEDSTOCK	SYSTEM	SCALE tpa	DATE
Heppenheim	Biowaste, OIW	LINDE	33000	1999
Herten	Biowaste	IMK	18000	1998
Himmelkron	Agricultural, OIW	AAT	2800	1995
Hirschfelde	OIW	AAT	3600	1997
Kahlenburg	MSW	Wehrle/Biopercolat	20000	2001
Karlsruhe	Biowaste	BTA	8000	1996
Kaufbeuren	Biowaste, OIW	BTA	2500	1992
Kempten	Biowaste	Kompogas	10000	1995
Kirchstockach	Biowaste	BTA	25000	1997
Lemgo	Biowaste, OIW	LINDE	38000	2000
Michaelisdonn	Agricultural, OIW	Krüger	35000	1995
München	Biosolids, OIW	Schwarting UHDE	86,400	1987
München/Eitting	Biowaste	Kompogas	24000	1997
Münster	Biowaste	BTA /Roediger	20000	1997
Neukirchen	Agricultural, Biowaste	AAT	55000	1998
Nordhausen	Biowaste	Haase	16000	1999
Oldenburg	Agricultural, OIW	Krüger	20000	1992
Pastitz/Rügen	Agricultural, OIW	Bioplan	100000	1997
Passau		Kompogas	13000	Nov 2004
Radeberg	Biosolids, Biowaste OIW	LINDE	56000	1999
Regensburg	Biowaste	TBW/Biocomp	13000	1996
Roding	Biowaste	AAT	7000	1996
Sagard/ Island Rügen	Biowaste, Agricultural, OIW	LINDE	48000	1996
Schwabach	Biowaste	BTA/ATU	12000	1996
Schwanebeck	Biowaste, Agricultural	Haase	50000	1999
Simmern	Biowaste	Kompogas	10000	1997
Wadern-Lockweiler	Biowaste, OIW	BTA	20000	1998
Wiessenfels	Biowaste	Kompogas	12,500	2003
Wittmund	Agricultural, OIW	Krüger	120000	1996
Zobes	Biowaste, Agricultural, OIW	DSD	20000	1986
Indonesia				
Bogor	OIW	Dranco		1986
Italy				
Bassano	Grey waste?	Valorga	52400	2004
Bastia/Brettona	Agricultural, OIW	RPA	300000	1982
Bellaria	MSW	Ionics Italbia	4000	1988
Marsciano	Agricultural, OIW	SPI	300000	1988
Rome	Mixed waste	Dranco	40000	2002
Thiene	Agricultural, OIW	KIKlos	60000	1990
Japan				
Kagoshima	Biowaste, Agricultural	Dranco		1998
Kyoto		Kompogas	1000 (demo)	1999
Kyoto		Kompogas	20000	Mid 2004
Netherlands				
Breda	Biowaste	Paques	10000	1992
Breda	OIW	Paques	25000	1987
Groningen	Grey waste	CiTec	85000	1999
Lelystad	Biowaste	Heidemij, Biocel	35000	1997
Tilburg	Biowaste	Valorga	52000	1994
Spain				
Alicante	Mixed waste	Dranco	30000	2002
Barcelona	Grey waste	Valorga	120000	End 2003?
La Coruña	OIW	AAT	34000	1993
Cadiz	Grey waste	Valorga	115000	2003/4?
Rioja		Kompogas	75000	Mid 2005
Sweden				
Borås	MSBW	YIT-VMT/	9000	1995
Helsingborg	Agricultural, OIW	NSR	20000	1996
Kalmar	Agricultural, OIW	VBB Viak/Lackeby	25000	1998
Kil	MSBW	CiTec	3000	1998
Kristianstad	MSBW, Agricultural, OIW	Krüger	73000	1997
Laholm	Agricultural, OIW	Krüger	37000	1992
Linköping	Agricultural, OIW	Purac	105000	1997
Uppsala	MSBW, Agricultural, OIW	YIT-VMT/Läckeby	30000	1997
Vanersborg	MSBW	YIT/VMT	20000	2000

COUNTRY / LOCATION	FEEDSTOCK	SYSTEM	SCALE tpa	DATE
Switzerland				
Aarberg	Biowaste	Dranco	11000	1997
Baar	Biowaste	LINDE	6000	1994
Bachenbülach	Biowaste, Yard	Kompogas	10000	1994
Bachenbülach	Biowaste, Yard	Kompogas	4000	2003
Dietikon	Biowaste	Kompogas	10000	2005
Frauenfeld	Biowaste, OIW	rom-OPUR	15000	1999
Geneva	Biowaste	Valorga	10000	2000
Jona	Biowaste	Kompogas	5000	2004
Lenzburg	Biowaste	Kompogas	5000	Nov 2004
Muhen	Agricultural, OIW	LINDE	5000	1986
Niederuzwil	Biowaste	Kompogas	13000	1997
Oetwil am See	Biowaste	Kompogas	10000	2001
Otelfingen	Biowaste	Kompogas	12000	1996
Rümlang	Biowaste, Yard	Kompogas	8500	1992
Samstagern	Biowaste, Yard	Kompogas	10000	1995
Villeneuve	Biowaste	Dranco	10,000	1999
Volketswil	Biowaste, Yard	Kompogas	10000	2000
Vuiteboeuf	Agricultural, OIW	LINDE	6900	1986
Wädenswil	OIW	Entec	5000	1997
Ukraine				
Zaporozhstol	Agricultural, OIW	Krüger	12000	1992
United Kingdom				
Leicester	Mixed waste	Hese	40-60,000	2005?
USA				
Greenboro, NC	Yard wastes	DEES	30000	2000
Moorfield, WV	Biowaste, Agricultural, Biosolids	Enviro-Control	3000	1996
Princeton, NC	Agricultural, OIW	DEES	3500	1999

Source: Adapted from IEA Bioenergy (2001) Biogas and More: Systems and Markets Overview of Anaerobic Digestion, Task 24, Energy from Biological Conversion of Organic Waste. Please note that this list is not completely up-to-date. There are new plants installed each year. We have tried to update this on the basis of our own research.

Figure 11: Capacity per Million Inhabitants and Percentage of Potential Theoretical Capacity



Source: L. De Baere (2003) State of the Art Anaerobic Digestion of Municipal Solid Waste, paper presented at Sardinia Landfill Symposium, 2003

5.0 AEROBIC PROCESSES

As with anaerobic treatment plants, aerobic plants vary in size and in their mode of operation. As well as home composting operations, there exist a variety of community and farm-scale plants which are suitable for smaller scale operation, as well as much larger industrial scale facilities. The scale of facility can be used to implement either centralised or decentralised strategies. Examples of the latter can be found in Austria and parts of Germany and Northern Italy.

Industrial scale facilities for treating biowastes containing kitchen wastes now have to be 'covered' systems. This means that systems cannot be open air systems, and will have to be either:

1. Fully enclosed systems, where the material is effectively sealed off from outside interference (other than aeration); or

2. Covered systems, in which the mass of material is not so much enclosed as housed. Typically, such systems will be covered windrows.

Systems can be divided into:

1. Batch systems, in which a mass of material is treated in one container or as one load; and

2. Continuous flow systems, in which materials can be added continuously over time.

Systems can be further sub-divided into:

- Dynamic systems, in which the material is agitated by paddles or augers; and

- Plug flow systems, which move the material through a process without agitation

In enclosed / covered systems, it is frequently the case that aeration is applied to the system by mechanical means. Systems can act with a 'blowing' (positive pressure) or 'sucking' (negative pressure) action. In systems which are not fully enclosed, the latter is believed to have certain advantages in terms of management of bioaerosols and odours since air can be sucked directly into a biofilter and the material is not so agitated by the aeration process (so operatives are less exposed to dust / bioaerosols).

5.1 State of Composting in Europe

In the 15 Member States of the European Union, there are around 1800 plants dealing with source-separated municipal biowastes. Of these, almost 40% (7 million tonnes of capacity) deal with garden waste only. Around 12 million tonnes capacity exists in Germany alone, whilst around 2 million tonnes is in place in Italy.

As indicated, the above figures are applicable to source-separated materials only. The capacity of compost (and to a lesser extent, digestion) facilities reflects the state of play in respect of source separation. Table 7 shows the relative progress made in different Member States. The 17 million tonnes or so of waste collected are from an estimated 50 million tonnes available, so the net capture rate for the EU-15 is around 35%.

Recent years have seen an increase in the importance of organic waste management in most European countries. The practice of source-separation of municipal biowaste for composting is now well-established in Austria, Germany, Netherlands, Luxembourg, Belgium (most notably, Flanders) and Denmark (though the Danish situation is focused predominantly on the capture of garden wastes). The practice is also diffusing swiftly in Italy, prompted by the so-called Ronchi Decree, requiring all provinces to achieve 35% recycling/composting by March 2003. The Italian experience is spreading in parts of other Southern Member States (such as France, and Spain, through ongoing developments in the Catalonia region).

There is growing appreciation of the role of kitchen waste collection in cost-optimised systems of waste collection and treatment, alongside an increasing awareness of the fact that low levels of soil organic carbon are becoming a limiting factor for crop production in Southern European agriculture. Other countries, notably Sweden and Finland, are also considering major increases in source-separation. Finland has established a target of a 75% capture-rate of biowastes by 2005. Sweden has instigated a variety of measures to promote composting as a means of meeting requirements for landfill diversion under the EU Landfill Directive.

Table 7: Amount of separately collected and composted bio- and green waste from municipal waste in the EU

Country	Total MSW	Organic MSW		Separately collected	Separately collected as% total	Separately collected and home composted as% total (inc home comp)
		excl home composting	incl home composting[1]	TOTAL		
Austria	2,800,000	800,000	1,570,000	600,000	75.00%	87.26%
Flanders	3,126,044	1,158,795	1,264,795	723,795	62.46%	65.61%
Denmark	2,780,000	973,000		652,000	67.01%	
Finland	2,510,000	1,004,000		93,000	9.26%	
France	28,000,000	9,800,000		1,600,000	16.33%	
Germany	49,100,000	9,000,000		7,000,000	77.78%	
Greece	3,900,000	1,833,000			0.00%	
Ireland	2,060,000	556,200		6000	1.08%	
Italy	28,400,000	9,542,400		1,500,000	15.72%	
Luxembourg	250,000	109,500		34,000	31.05%	
Netherlands	8,220,000	3,452,400		1,700,000	50.00%	
Portugal	3,800,000	1,406,000		14,000	1.00%	
Spain	17,200,000	7,585,200		50,000	0.66%	
Sweden	3,810,000	1,500,000		400,000	26.67%	
UK	34,000,000	10,880,000		618,517	5.68%	

Sources: Amlinger, F. (2000) 'Composting in Europe: where do we go?' *Paper for the International Forum on Recycling*, Madrid, 14 November 2000; Barth, J. (2000) '*Composting, quality assurance and compost utilisation - sustainable solutions in the European countries*', unpublished mimeograph; Hogg, D. *et al*. (2002, forthcoming) *Economic Analysis of Options for Dealing Biodegradable Municipal Waste*, Final Report to the European Commission.

[1] *In most of the European countries no statistical data about home-composting is available, so an estimation about full extent of the potential of organic waste is very difficult.*

5.2 Summary

As with anaerobic systems, there are a variety of aerobic composting systems available in the market. At the EU level, the market for aerobic systems is much more mature than for the anaerobic systems. This is reflected in the relative take-up of the technologies, with composting accounting for some 14 million tonnes of the 17 million tonnes or so of treatment capacity for separately collected biowaste.

However, the take-up of digestion relative to compost has increased significantly in recent years. There are a number of reasons for this ‘acceleration’ in the take-up of digestion systems:

1. Greater experience with the process;
2. Improved operational knowledge (with consequent process optimization and cost reductions);
3. A desire to contain processes, especially in urban areas with a view to odour minimization;
4. Increased significance accorded to the desirability of generating renewable energy.

Hence, we would expect to see, over time, a rationalisation of the respective roles of composting and digestion in which, for example, composting technologies continue to be the approach of choice for garden wastes (partly on the basis of costs, because of continuing acceptance of open-air systems for garden waste composting), whilst digestion systems treat wetter food waste fractions. The potential to blend digestates with garden waste composts or add them to aerobic composting processes is an area of considerable interest at present.

6.0 STUDIES CONCERNING, AND CASE STUDIES OF, AD PLANTS

A comprehensive literature review covering all reports and case studies is beyond the scope of this work. The following review looks briefly at existing UK studies, these relating principally to agricultural wastes.

6.1 UK Studies

6.1.1 Development of Policy and Focus

In the UK, a number of studies were carried out under the auspices of the Energy and Technology Support Unit (ETSU) as part of the DTI's New and Renewable Energy Programme. The work can be traced back to the early 1980s following Ader Associates' study of the potential for biomass conversion to energy.[18] The study noted that the technology was only used on a large scale for sewage treatment, but that it was also used to treat animal manures, with the balance of interest being split between pollution control and fuel generation. The study noted that some work was ongoing in the USA regarding mixed municipal wastes, but that the low volatile solids content and the difficulty of handling the material resulted in poor gas yields and high costs. A model to estimate 'break-even' points was developed for digesters of cattle manure, pig slurry and grasses.

This was followed in 1984 by a study by Richards suggesting that four major markets existed for the technology; domestic sewage; industrial effluents; agricultural wastes and crops; and domestic landfill. Regarding agricultural wastes, it is clear that the Department of Energy (as was then) assisted in design, construction and evaluation of some farm-based units. The summary states, with regard to livestock manures, that:

> *In addition to laboratory and pilot-scale digesters, two fullscale units have been constructed, both operating on piggery waste which is amenable to digestion, gives good gas yields and is a cause of significant environmental concern because of its odour. To date, however, there have been problems with ancillary equipment failure and poor feedstock availability, and it is clear that farm digesters will only operate satisfactorily where farmers have adequate slurry or waste collection systems - the exception rather than the norm. Problems are also associated with the compositional inconsistency of the feedstock and the fact that it is usually fibrous and cold. <u>Nevertheless, on some farms, anaerobic digestion may make sense environmentally, with energy production being of only secondary importance. This would apply on numerous sites if tighter pollution legislation were to be enforced.</u>*[19]

The emphasis on farm wastes and landfills appears to have been established from this date onwards, though some investigations on industrial effluent also occurred. Trials were reported on prototype units in a 1986 study looking at pig slurries and biomass crops as feedstocks. The study also looked at the value of digestate as a fertilizer and noted:

> *High growth yields were obtained compared with those achieved with the application of a commercial fertiliser, and it was also established that the fertiliser value of digester effluent was*

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[18] Ader Associates (1981) *Conversion of Biomass to Fuels by Anaerobic Digestion Phase 1: Review and Preliminary Assessment,* ETSU B3118a. It is worth noting also the study by The Open University (1981) *Resource Mapping of Agricultural Wastes and Residues* National College of Agricultural Engineering, ETSU-B-1055

[19] K M Richards, ETSU 1984 Anaerobic digestion: a credible source of energy ETSU L/2

> *slightly better than that of untreated slurry - a valuable finding as the effluent has a much reduced pollution load, causes less soil damage than slurry and can be transported more easily .*[20]

In 1987, a review of the Department of Energy's research programme into digestion of agricultural wastes took place. It noted the two prototype full-scale digesters for treating pig-slurry but it also noted that by 1983, the uncertain economic prospects were already casting a cloud over the relevance of that, and subsequent research work. The report alluded to the environmental benefits, but the lack of clear drivers pushing farmers to use the technology. The summary report noted:

> *Very few anaerobic digestion plants in Europe and the UK have achieved economic success, and there is little likelihood of commercial farm digestion becoming more economically viable in the short term. There has been little progress, despite research, in improving fullscale digestion efficiencies; capital investment costs need to be significantly reduced; growing and harvesting crops for feedstock is likely to be uneconomic, even if high gas yields were to prove possible; and there are cheaper ways of dealing with farm wastes given current legislation.*
>
> *At current energy prices, an acceptable rate of return is only likely to be achieved if:*
>
> - *the feedstock is of good, consistent quality*
> - *a credit can be given for environmental benefits*
> - *the gas supply can be fully and profitably used on the farm.*[21]

Elsewhere, the report stated:

> *On-farm biogas production ... is technically feasible but the economic potential remains doubtful. Unless environmental pressures are increased concerning disposal of farm wastes, further research and development into agricultural digestion systems cannot be justified."* [22]

Changes in legislation and other factors led to another study in 1990. The key changes were:

- Changes in legislation regarding handling of slurries;
- The arrival on the scene of the Non-fossil fuel Obligation (NFFO) following the Electricity Act of 1989;
- The awards available through the Farm and Conservation Grant Scheme for upgrading waste-handling facilities (50% of the capital costs thereof up to a maximum of £37,500); and
- The growth in interest in organic farming.

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[20] Department of Microbiology, University College, Cardiff (1986) *Research into the Development of Prototype Units for the Production of Biogas Methane from Farm Wastes and Energy Crops* ETSU B 1118. The same organisation conducted a study, published in the same year, regarding more theoretical aspects of digestion (Department of Microbiology, University College, Cardiff (1986) *A Microbiological Study Into Processes Controlling Anaerobic Digestion*, ETSU B 1129).

[21] R E H Sims, Massey University, New Zealand, K M Richards (1987) *Potential for Biogas on Farms in the UK* ETSU R-41.

[22] R E H Sims, Massey University, New Zealand, K M Richards (1987) *Potential for Biogas on Farms in the UK* ETSU R-41.

The reports conclusions, however, seemed merely to reinforce those of earlier studies suggesting that though there were environmental benefits to be gained, the legislation did not do enough to ensure that incentives were in place to realize these. Hence, the economic case was still deemed to be weak.[23]

Developments in Denmark (after 1986) evidently attracted some attention and another study took place in 1993.[24] By this time, another potential legislative driver – the Nitrate Directive – was coming into view. A review of practice at the time revealed that despite significant research, and marketing of 'packaged products', take up of digestion had been slow. Only 43 digesters were in place on farms across the UK, of which 25 were thought to be operational. The study reported that at least seven had been decommissioned, usually after only three to five years' operation due to '*a sharp increase in maintenance costs.*' It noted:

> *Problems are frequently experienced with waste-handling systems, sedimentation and poor quality feedstocks. The gas produced is rarely fully and effectively used and, despite the sale of by-products, projects are often difficult to justify economically unless the need for odour control is paramount.*
> *Trials carried out during the 1980s have shown that using biogas for heat rather than for power is the better option for most typical dairy farms with more than 200 cows. A modest profit may be possible at this level as long as there is 50% grant aid and, more particularly, a reliable and valuable market for the separated fibre. Electricity generation is unlikely to be viable, even under the Non-Fossil Fuel Obligation, unless significant fibre sales can be achieved. Furthermore, the costs of entry to such a scheme are likely to be substantial.*

On the basis of Danish experience, the study estimated what would be required for centralized AD (CAD) systems to just break even. It was estimated that a project for which grant aid was available for 50% on all capital and where capital was amortised over ten years at 15% rate of interest would have annualised costs of the order £1.3 million. A small £1,394 per annum profit would be generated only where the following assumptions held true:

- feedstock was 88% agricultural and 12% industrial
- electricity output was 1MW (8760 MWh/year)
- heat output was 60 TJ/year (17 million kWh/year)
- electrical energy sales were concluded at 7p/kWh
- sales of hot water and fibre were guaranteed.

The study noted that if markets for the hot water and fibre were not forthcoming, the project would make a loss. A market for the fibre alone would make the venture possible, even with grant aid limited to 30%. If the high specific gas output were not achieved, then the energy benefits would be reduced, and the venture would depend on environmental benefits and on co-operation between livestock farmers, water companies, electricity producers and managers of the land on which the digested effluent may be effectively used. The study concluded, perhaps not surprisingly, by noting that unless a range of conditions – most of them in the gift of Government to deliver – were in place, then economic viability could not be ensured.

Although a 1994 study on the feasibility of equity and debt financing for CAD schemes reported in a more upbeat tone, the conclusions were not, in essence, dissimilar. The study looked, initially, at the project under conditions where the unit price for power generated was estimated at 10.75p/kWh. This

[23] F EMosey, VFA Services Ltd (1991) *Potential for Biogas on Farms in the UK: 1990 Update,* ETSU B 1295

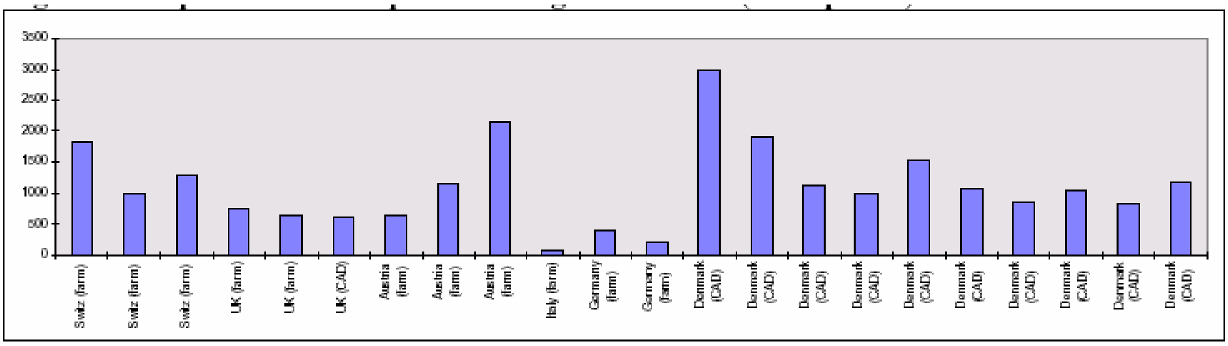
[24] ADAS, Silsoe (1993) *Anaerobic Digestion in the UK: a Review of Current Practice*, ETSU B/FW/00239/REP

price would, it was suggested, secure an IRR (internal rate of return) of 28.4% (or 21.6% in real terms). If fibre could be sold at £30/m3, it was suggested that the same IRR could be achieved at power prices of 8.4p/kWh and at 6.34p/kWh, an IRR of 21.3% (15% in real terms) might be realized.[25]

The potential scope for development of a UK based plant appears to have been followed up given the decision to move forward with an investigation into relevant planning issues, published in 1995.[26] By this time, the number of operational plants had fallen to 22. This study visited the facility at Newlands Mill Farm in Cumbria as well as a Danish plant to seek to understand relevant issues.

Yet another ETSU supported study on the economics of AD on agricultural wastes was undertaken in 1998.[27] This looked at the economics of plant under various assumptions concerning the revenue gained from outputs, and the capital and operating costs of facilities. The study looked at both larger centralized digestion plants, and smaller, on farm units. It reviewed information from some existing plants, and found that capital costs in particular varied significantly across the plants studies.

Figure 12: Capital Costs per m3 of Digester Volume (1997 ECU)



Source: I. Higham (1998) Economics of Anaerobic Digestion of Agricultural Waste, October 1998.

Under more pessimistic assumptions for the plants, the economic position was generally unfavourable. However, sensitivity analysis showed that the economic indicators varied with changing each of the cost and revenue parameters individually. Under revised base case assumptions, designed to indicate costs and revenues which should be achievable for each of the generic plants, much more favourable results were achieved with payback periods and IRR values which were deemed to be likely to be economically attractive.

6.1.2 Northern Ireland Cases

Virtually all UK anaerobic digestion plant has been dealing with animal wastes. This is beginning to change (see Section 6.1.3 below). There have been plants in Northern Ireland for several years. Brief descriptions are given below. Some are still operating. They have all been based upon animal wastes as feedstocks.

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[25] Sceptre Management Ltd (1994) *Equity and Debt Financing for Centralized Anaerobic Digestion of Farm Wastes: a Feasibility Analysis*, ETSU B/00/00173/REP

[26] The Barton Willmore Partnership (1995) *Review of Planning and Environmental Issues Relating to Centralised Anaerobic Digestion Facilities* ETSU B/M4/00487/09/REP

[27] I. Higham (1998) *Economics of Anaerobic Digestion of Agricultural Waste*, October 1998.

Waringstown

This facility was installed in 1992 at Lyttle's Farm. The plant was designed to operate on broiler poultry and pig manure, but actually operated on broiler poultry and cattle manure. The solids content of the waste was around 20-25% and the facility is intended to operate in a plug flow mode in the mesophilic range. A CHP (combined heat and power) Unit is used to generate energy from the plant. The digestate is subjected to a post-treatment aerobic composting phase and is marketed as a soil amendment.

More recently, we understand the Waringstown plant has started to treat commercial and industrial wastes.[28]

Coleraine

This facility is similar in process to the Waringstown operation and treated Broiler Poultry and Cattle Manure with a Total Solids content of 20-22%. The plant operates in the mesophilic mode. The outputs are Liquid effluent to 'pay' cattle slurry provider and solid digested fibre which is composted post-treatment for use as golf course amendments and a soil improver.

Cloughmills

This facility, at McGuckian's farm, uses pig slurry with a total solids content of around 15%. It operates in mesophilic mode. The plant was built to assist with the disposal of pig effluent which was a farm limiting factor, the unit produced excess gas which was not used. Fibre from the plant was sold for further processing. The potential of the process and the site has been proved over the years and the owner won a NFFO (Non-Fossil Fuel Obligation) contract in 1996 to provide the grid with up to 250kwe. of power for 15 years. The site is being redesigned to accommodate a larger digester (possibly incorporating the existing digester) with full CHP capacity - to be installed subject to contracts. Slurry is landspread using a large tanker.

Toomebridge

This small facility was installed in 1989 and operated on cattle manure and silage effluent. With a 15-20% total solids content, the facility operated in a semi-batch load at mesophilic temperatures. Liquid fertiliser is applied to grassland and for some time, fibre has been separated for compost production. This unit has reportedly removed the need for imported fertilisers and has significantly improved farm economics. Its main use is the production of stable liquid fertiliser spread using low soil compaction methods. The benefit has been the removal of fertiliser from the farm budget.

Portglenone

This 1985 facility of 210 cubic meters capacity operated on beef cattle manure and silage effluent. This has total solids content of 10-12%. The facility operates in plug flow mode in the mesophilic range.

The digester was designed in 1984 and was built from a kit of parts and assembled under the supervision of James Murcott of Farm Gas. It was originally conceived as providing the gateway to large scale organic farming, integrating farming of cattle using organic grass / clover/grain feed, with the production of organic oats for human consumption from the digested liquid fertiliser.

Biogas is sent to boilers at the Our Lady of Bethlehem Abbey a quarter of a mile away and the unit heats the monastery for 220 days a year when the cattle are housed. Liquid effluent is used in organic grain

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[28] Personal communication with Les Gornall, Practically Green.

production for human consumption. Some is refined for golf course liquid fertilizer. Solid digested fibre is composted for golf course amendments and soil improvers.

This unit won the 1986 Pollution Abatement Award from the Royal Society of Arts/Confederation of British Industry and the Department of the Environment. In 1987 the system came equal second in a field of 1500 entries in the European Year of the Environment Awards in Brussels.

Recently, this plant ceased to operate and the assets were sold off. This was due to the number of monks (upon whom the plant had relied for operation) being reduced.[29]

6.1.3 Recent Years – AD of Municipal Wastes

Only in relatively recent years does AD appear to have been perceived as a technology of relevance for treating municipal wastes (at least, in respect of references to UK studies thereof). The literature review above reflects this. Since 1998, the following studies have appeared:

1. IWM, (1998) Anaerobic digestion, Institute of Wastes Management,

2. P A Wheeler, L de Rome, A J Poll, A van Santen (1999) Waste Pre-Treatment: A Review, Agency R&D Report Reference No PI-344/TR

3. S. Mclanaghan – Delivering the Landfill Directive: The Role of New and Emerging Technologies

Each of these has increased the level of attention given to anaerobic digestion technologies as a means to divert municipal wastes from landfill. Increasingly, local authorities are looking at digesters to provide part of their waste management solution. For example:

- For some time, the possibility of having an anaerobic digester in place in Southampton has been considered (the project ran into problems related to procurement issues when PFI (Private Finance Initiative) funding was sought for the project). Surrey, Kent and Cardiff have also considered AD systems in the past;

- In the East Sussex contract, Onyx are likely to introduce digestion technology at some stage;

- In Leicester, the award of a PFI contract to Biffa is centred around a digestion system, though one which is designed to treat organic wastes extracted from residual waste after this has been subjected to ball-milling and screening (the plant will treat the undersieves from the process);

- Thames Waste Management was seeking construction of an AD plant as part of the Hereford and Worcester contract; and

- In Essex, digestion-based solutions have been the focus of much attention.

Much of the focus seems to be, unfortunately, still on the treatment of OFMSW rather than SOFMSW. This is perhaps not surprising given the definitional issues which have plagued the development of digestion of source-separated organic wastes (see Section 8.2).

An exception was the Greenfinch facility in South Shropshire, though this facility was more of a demonstration project, conducted on a relatively small-scale. The company conducted a trial, the first of its kind in the UK, between October 1999 and April 2001 involving 1,500 households. Local

[29] Personal communication with Les Gornall, Practically Green.

householders separated kitchen waste collected every week in white bags from the kerbside and delivered to the Greenfinch's Biowaste Digester nearby.

The plant has since been replaced by an R&D project to recycle kitchen waste from 150 households, investigating mass balance, energy balance and pathogen destruction in two biogas plants operating at 35°C and 55°C. The energy was used for heating greenhouses and the digestate. Recently, the plant was forced to cease operation as a result of the UK ABPR.[30] The project did give valuable information on the performance of the facility and of the linked 'kitchen waste only' collection system.

6.2 Summary

A large number of studies have been undertaken in the UK concerning the use of anaerobic digestion in the management of various types of waste. Until recently, much of the focus has been on livestock wastes. However, almost every study has suggested that until there is some requirement for farmers to deal with wastes in different ways, the economics of the process are not entirely favourable.

As regards municipal wastes, the low level of landfill costs in the UK has implied that digestion systems have been seen as something 'of interest', but with little prospect for practical application. This is now changing, but even though it is changing, much interest is focused on the use of digestion for treating residual wastes as a means of 'landfill diversion'. The term 'landfill diversion' caries with it connotations of the 'the need to do something different', rather than a positive choice in favour of a particular technology. Digestion processes offer clear prospects for treating source-separated fractions of organic waste in such a way that renewable energy is generated, a valuable source of nutrients is produced (which, if further stabilised, has different agronomic properties) whilst targets for 'landfill diversion' and (most recently) recycling are met. As such, digestion processes may offer a positive choice for dealing with organic wastes subject to economic considerations.

[30] Personal communication with Michael Cheshire, Greenfinch.

7.0 CASE STUDIES FROM EUROPE

7.1 Dry, Single-step, Mesophilic - Valorga Plant, Tilburg, Netherlands

7.1.1 Background

Tilburg, in the Netherlands, is in the Nord-Brabant Province, around 30 km from Eindhoven.[31] The Tilburg plant began its operation in 1994 and treats primarily vegetable, garden and fruit waste (VGF). It is operated by the intermunicipality SMB (Samenwerkingsverbrand Midden-Brabant), which includes 9 municipalities. SMB chose to use a digestion plant since there was the prospect of locating the plant close to the landfill, where biogas was already being treated to produce energy.

7.1.2 Plant Description

The plant capacity is 52,000 tonnes/year. The plant occupies a site of 1.6 hectares and accepts mainly source separated 'VGF' material (i.e. vegetable, fruit and garden waste). However, the municipal waste management plan for the province has encouraged the separate collection of VGF waste alongside dirty paper and card. The digestion system is designed, therefore, to treat either 52,000 tonnes of 'pure' VGF material, or a combination of 40,000 tonnes of VGF material plus 6,000 tonnes of non-reusable paper and card.

SMB collects and separates municipal waste from the participating municipalities. The aim of the SMB, in the new waste disposal plan, is to separately collect three quarters of the available VGF material. The VGF waste is collected fortnightly from green bins into which the material is transferred from buckets stored in the kitchen. The plant effectively serves 380,000 or so inhabitants (so the materials capture is of the order 100kg per inhabitant, or more than 250kg per household equivalent in the UK). The material is typically 75% kitchen and garden waste (of which, approximately 60% is garden waste and 40% if kitchen waste), and 25% paper, card and impurities. Seasonal variations are significant so the material varies in composition (from 35-38% dry matter, but with volatile solids content varying from 35 to 65% over the year).

A schematic of the plant is shown in Figure 13. The plant consists of two digesters, each of 3,300m^3 capacity. The incoming waste is tipped on a floor and then screened at 80mm hole size. The oversieves are manually sorted on a conveyer and the rejects – approximately 5-10% of the input – are sent to landfill. The clean oversize fraction is also subjected to magnetic separation and is then reduced in size through slow speed shearing process.

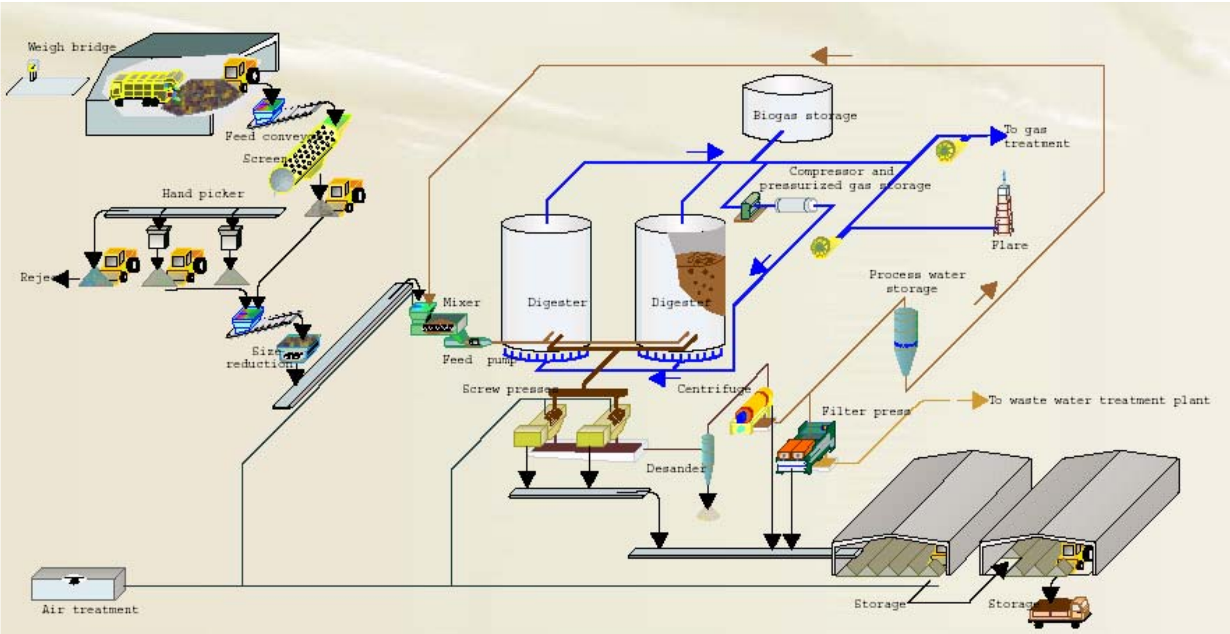
The pre-treated material is then conveyed to the mixer containing two screws. The waste is mixed with process water and 20-25% digested material (used as inoculant) and is heated by steam injection. The material is then pumped via a feed pump to the two (identical) digesters. So as to avoid mixing incoming and outgoing material, the Valorga process uses a vertical wall covering almost the complete vertical cross section. The agitation is through blowing compressed biogas at intervals through the material from pipes at the bottom of the vertical tanks. Different sections are monitored and subject to individual control. This mechanism avoids using mechanical installations in the digester to obtain adequate

[31] Information for this case study is from two sources: Valorga Internatinal information, and Leif Wannholt (1999) *Biological Treatment of Domestic Waste in Closed Plants in Europe - Plant Visit Reports*, RVF Report 98:8, Malmo: RVF.

agitation. The outlet pump is on the opposite side of the vertical wall to the input pipe, both being located at the base of the digester.

The retention time in this plant is 20-24 days at a mesophilic temperature of 35°C-40°C (typically, 38° C). Average dry matter content is around 25-35% by weight. Temperature, gas production and methane content of gas are monitored continuously whilst pH, dry matter content and inerts are measured manually at intervals.

Figure 13: Plant Schematic of Tilburg Plant



Source: Valorga International

The residue is then de-watered in two parallel screw presses. The resulting digestate has a water content of 45-50% by weight. Sand (which can form as much as 30% of the input – there is a considerable amount in the garden waste element) is removed from the effluent in a hydro-cyclone, whilst a centrifuge is used at a later stage to remove lighter particles. The sand fraction is landfilled. The lighter fraction – typically organic in nature – is recombined with the solid residue.

Dewatered solids are transported by conveyor to a separate enclosed building where the material is formed into static piles for aerobic composting. There is no forced aeration, but the exhaust gas is sucked through an acid washer before being passed through a biofilter outside the building. There is no water excess or demand at this point. There is no agitation in the process, which lasts seven days. The temperature (monitored manually) tends to begin around 45°C and fall to 30°C at the end of the process. The end product has a dry matter content of around 60%.

Currently, 12 people are employed at the VFG digestion plant.

7.1.3 Performance Data

The plant produces around 18,000 tonnes of compost yearly. Self-heating and respirometric tests have shown that the organic amendment coming from the plant displays a high level of maturity, and quality requirements for compost are met. But, because of lack of finances, the post-treatment plant for the handling of the digestate to produce quality compost, was not built. This means that even though it is possible to produce high quality compost, this has not been done to date. Today, thoughts are centred on building this final part or placing this after treatment elsewhere, in relation to the permit.

Wannholt gives data on the compost quality. The contaminant levels are low. Though the product is of high quality, it is used for landfill restoration by the operators (who also operate the landfill). The plan is to make use of the material in agriculture at a later date.

The cleaned effluent is stored in a process water tank and is heated by steam injection. Subsequently, it is re-used in the mixing process (for the pre-treated input). Excess effluent is around 20% of the input, or approximately 11,000m3 per year. It is discharged to sewer and treated through conventional sewage treatment works.

Technical figures describing the biogas plant are the following:

- Digestion temperature: 37-40 °C
- pH: 7.1
- Retention time: 24 days
- Organic volume load: 7.0-8.6 kg VDM_1/m_3*day
- Methane content: 55 %
- Methane production: 200-250 Nm^3/tons VDM
- Annual Capacity: 52,000 tons of VFG
- Annual Load: 40,000 tons of VFG

The biogas production varies (especially with the ratio of card to VGF material). Average values are around $82m^3$ per tonne, though values can be as high as 106 m^3 per tonne of waste. Expressed in terms of volatile solids fed to the digester, the average is around $400m^3$ biogas per tonne VS, but can be as high as 550 biogas per tonne VS in winter. The variation is due to the changes in composition which occur over the year (the specific biogas production is higher in the winter when there is less of the woody material which is more recalcitrant in digestion processes). Composition is typically 56% methane, so methane production tends to be of the order $200\text{-}250m^3$per tonne VS. The gas is carried out from the top of the digesters and is piped into a buffer storage tank (a low pressure balloon inside a cylindrical tank), and then to a gas cleaning system (along with gas from a nearby landfill). Some of the gas is compressed and used in the agitation process (but none of this is 'lost'). Gas refining consists of compressing, cooling, scrubbing, and drying.

The plant produces 3.0 million Nm^3 biogas per year with a methane content of approximately 55%. This is converted /upgraded in the upgrading plant to 1.6 million Nm^3 of gas with "natural gas quality". Afterwards it is transferred into the gas distribution network. The biogas has a calorific value of about 20 MJ/ m^3 while the refined gas contains 31.7 MJ/ m^3. The yearly energy production is 18 GWh, of which 3.3 GWh (300,000 Nm^3 of natural gas) is used for process heat at the plant itself which means that 14.7 GWh is sold to the gas distributor. The hydrogen sulphide content (H_2S) observed in the biogas at Tilburg is very low (from 0 to 100 ppm).

The investment to the biogas plant was approximately £12 million, or around £250-300 per tonne of capacity. The agency for energy and environment in The Netherlands, Novem, granted approximately £1 million. The balance was invested by SMB. The main sources of revenue are gate fees paid by the municipalities for waste treatment and the sale of natural gas. Between 1994 and 1999, the average fee for waste treatment was around £50-60 per tonne resulting in an average annual revenue of £2.2 million. Another report suggests a gate fee of €65 /tonne of VFG (or around £46 per tonne).

Valorga have produced a mass balance for the plant, which we take to be a balance under the assumption that the plant is operating at full capacity. We have normalized the information to one tonne of waste input (see Figure 14).

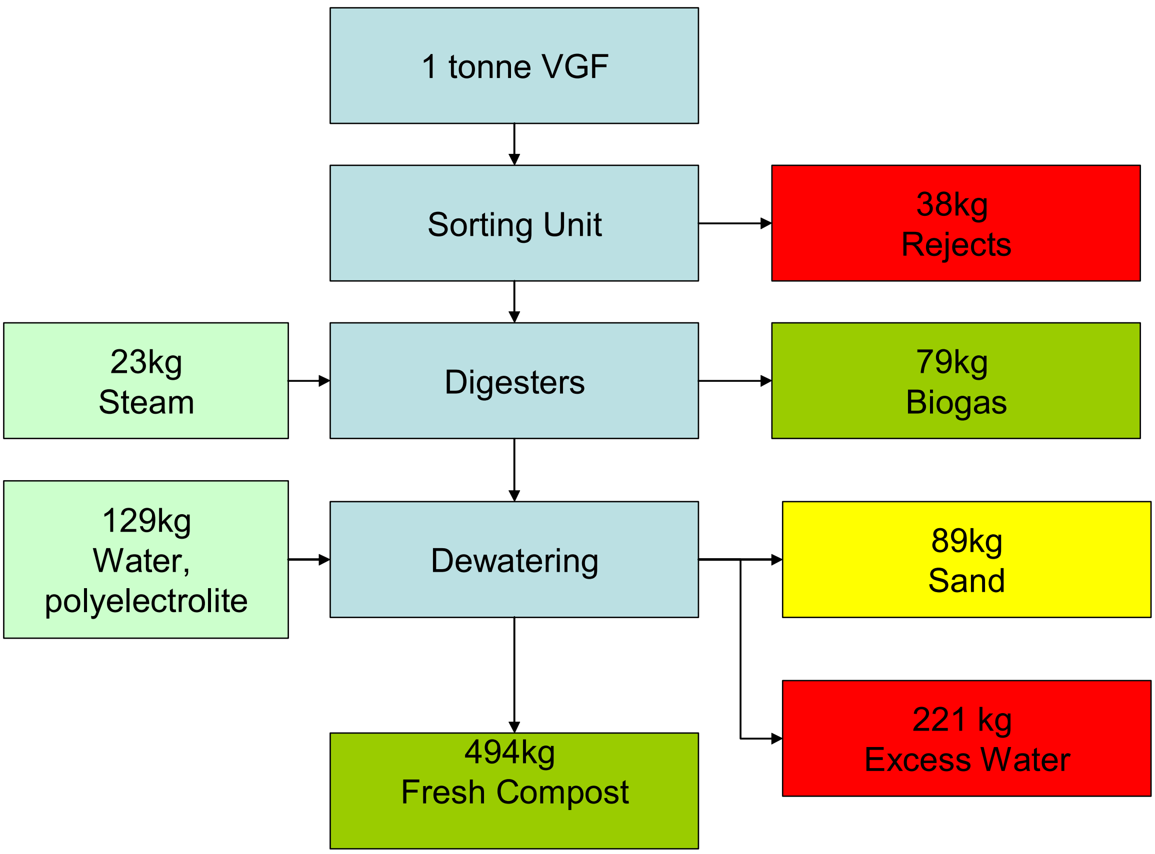
7.1.4 Gas Upgrading Plant

The gas upgrading plant was built in 1986, when utilisation of the gas from the landfill began. It now receives biogas from three different sources, the landfill site, the VFG digestion plant and a neighbouring sewage treatment plant that from time to time delivers surplus biogas.

Normally, this plant uses its biogas in a small co-generation unit. On a yearly basis, 30% of the handled gas is from the VGF digestion plant and 70% from the landfill site. The treatment plant includes a humid washer to remove carbon dioxide by gas-liquid contact. Some of the surplus CO_2 is used for cleaning purposes, the rest is emitted into the atmosphere. Biogas treated to reach natural gas characteristics is injected into the Tilburg City distribution network. Total investments in 1986 amounted to €3.6 million (probably around £3 million in 2004 sterling). The production price reported by one source is €0.14/Nm^3. Regarding technical specification (figures for 1996-99) the following figures apply:

- Maximum capacity (input, biogas) 2000 Nm^3/h
- Maximum capacity (output, upgraded gas) 1300 Nm^3/h
- Normal load (biogas): 900–1700 Nm^3/h
- Yearly production (upgraded gas): 6 mio. Nm^3

Figure 14: Mass Balance for Tilburg Facility



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7.2 Dry, Single-step, Thermophilic – Dranco Plant in Brecht (Belgium)

IGEAN is the intermunicipality covering the towns and villages in the northern Antwerp region.[32] At the end of the 1980s, it decided to pursue the possibility of introducing an anaerobic digestion plant for the treatment of organic wastes. The choice was partly influenced by EU Directives encouraging renewable energy and the possibilities for obtaining support for such projects, especially those related to biogas.

The first plant in Brecht, located about 25km north-east of Antwerp, started operation in 1992. This plant – DRANCO1 - had a capacity of around 10-15,000 tonnes/year of source separated biowastes. The plant started small so as to avoid the potential for over-investment, not least since it was not known how much source separated biowastes would be captured through the collection system. Dranco1 effectively served around 26,000 households.

The experience with the plant, as well as successful implementation of source separation systems, led to the decision to construct a second plant, Dranco2, with a capacity of 45-50,000 tonnes , as well as a wastewater treatment plant for the treatment of process water and run off from the treatment centre.

The new unit was completed in 2000, and now handles around 50,000 tonnes per annum from a population of 300,000 to 400,000 in 24 communities. It is operated by three persons /shift (two shifts/day). The plant closes overnight and for the weekend. Approximately 165 tonnes/day of source separated kitchen wastes, garden wastes and other feedstocks (including non-recyclable paper) are received. The materials processed are, on a wet weight basis, approximately 15% kitchen waste, 75% garden waste and 10% unrecyclable paper. The degree of conversion of the wastes is of the order 60%.

A process flow diagram is shown in Figure 15. The organic materials are unloaded onto an enclosed tipping floor and fed onto a walking floor-type bunker that slowly feeds to a conveyor in the screening/mixing room. The screens and mixers separate plastics and other contaminants from the feedstock, conditioning it for further mixing. Two trommel-style chambers receive the crudely premixed organics which stay in the first chamber for two to three hours, then reside in the second for another six

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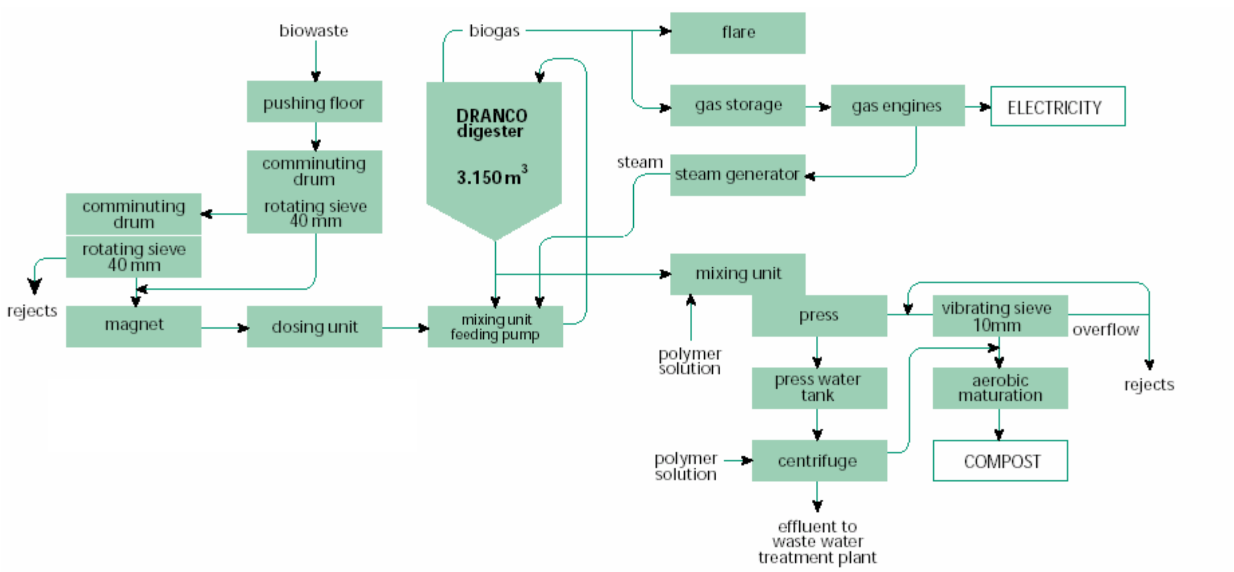
[32] Information for this case study is from Organic Waste Systems and from Leif Wannholt (1999) *Biological Treatment of Domestic Waste in Closed Plants in Europe - Plant Visit Reports*, RVF Report 98:8, Malmo: RVF.

to eight hours. Each chamber rotates, moves and breaks up the organics into a 10 mm size product. Oversized materials are screened off the end of the second chamber and dumped into large roll-off boxes for disposal.

Figure 15: Flow Diagram of the Brecht Facility



Source: Organic Waste Systems

Screened and mixed materials are then fed into a dosing unit that injects steam to reach 55°C (pathogen kill) and mixes in previously digested materials for the purposes of inoculation. Material is pumped to the top of the reactor (digester) where residence times are around 14 days in the new installation, which is an improvement over the previous design, for which retention times could be as long as 20 days.

Substrate is fed into the reactor at a rate of around 100m3/hr. The biogas is stored in a gas-storage unit. At the new plant, it is used as fuel for two 657kW generators, heat from which is passed through a heat exchanger and used to produce steam for substrate heating. The facility uses some electricity, and exports the surplus to the national power company.

Floculant is added to the digested material, which is dewatered by a press before being processed on a vibrating screen to remove residual contaminants (plastic, sticks, etc.). Approximately 10 per cent is removed. It is then cured aerobically for about 10 days in a facility with in-floor air ducts, turning mechanisms and sliding wall access. Exhaust air is treated in a biofilter.

Table 8 gives a basic mass balance for the plant.

Table 8: Brecht AD facility outputs per ton of feed material

	Quantity (tons)
Compost product	0.33
Biogas	0.14
Wastewater	0.42
Solid Residue	0.105

Source: Based on Leif Wannholt (1999) Biological Treatment of Domestic Waste in Closed Plants in Europe - Plant Visit Reports, RVF Report 98:8, Malmo: RVF.

7.2.1 Dranco 1

The investment costs for this plant were of the order £3.5 million. This corresponds to around £300 per tonne. The operating costs were quoted by Wannholt at around £40 per tonne. This seems a high figure. Revenues amounted to around £4 per tonne of compost, whilst energy sales generated around £53,000. The compost is known to be of high quality and is marketed under the name of Humotex. Discussions with representatives of Vlaco, the Flemish body with responsibility for compost standards, makes this clear. At a 10% rate of return, the estimated unit cost would be of the order £64.52.

Table 9: Brecht AD facility outputs per ton of feed material

Costs and revenues	Total	Per tonne feedstock
Item		
Investment Cost	£3.5 million	£31.62
Administrative & Labour Cost**	0.15 million p.a. (est)	£11.54
Operational Cost**	0.15 million p.a. (est)	£11.54
Annual Charges**	0.2 million p.a. (est)	£15.38
Revenue		£4.10
Compost		£1.47
Net cost		£64.52

Source: Estimated based upon various sources.

7.2.2 Performance of Dranco 2

Key characteristics of the Dranco 2 plant are:

- Digester capacity 3,150m3
- Waste Used Kitchen (10-40%), Garden (40-75%), Paper (14-20%)
- Biogas production 118m^3/tonne waste
- Methane content of biogas 55%
- Electricity production 8,500MWh/year (approx 170 kWh per tonne)
- IGEAN investment €16 million (approx £11.5 million)
- Treatment cost €82 per tonne (approx £59/tonne)

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7.3 Wet, (pseudo-) Multi-step, Mesophilic - BTA Plant, Wadern-Lockweiler (Germany)

The plant at Wadern-Lockweiler treats 20,000 tonnes per annum of biowaste and commercial waste.[33] The facility involved the redevelopment by BioSaar GmbH of a former facility for the removal of dead animal bodies.

Picture courtesy of BTA

All vehicles entering the site pass over a weighbridge. After weighing, the biowaste is put into different bunker systems (flat- or deep bunker tanks) in the reception hall, according to its waste characteristics. The source separated biowaste from households and the solid organic commercial wastes are put on the flat bunker. The material is then transferred by a front loader into the treatment phase.

Solid or packed components of the biowaste are roughly disintegrated by a screw mill, for better handling. After passing through the screw mill, ferrous materials are extracted by magnet. The material is then transported to the pulpers.

Liquid wastes are either emptied into a deep bunker or pumped into storage tanks, from where the material is directly fed into the pulpers.

The further separation of contaminants and the processing of the organic components occurs in the pulpers (and this applies to both types of waste, liquid and solid). By addition of process water and flow-dynamical forces, due to continuous stirring, the biowaste is effectively dissolved, and a thick, pumpable suspension (pulp) with high content of dissolved organics is created.

Light contaminants such as plastics, wood, and textiles are separated by rakes from the pulp and are put into a press to reduce the water content. Heavy components (e.g. glass, stones, tiles, residual metal etc.) are collected in a trap for the heavy fractions, which basically sink, and separated from the pulp. Separated light as well as heavy contaminants, which are not degradable, are then dried in a stream of air, heated up to about 80^o C, for 3-5 days. This process is effectively carried out for reasons of sanitation, as well as to reduce the weight of the material, so minimising transport expenses and the costs for disposal (which are related to tonnage).

As there are still fine inert materials (such as sand and glass shards) remaining in the pulp, these materials are separated from the pulp by a grit removal system (a hydrocyclone), after which they are stored in containers for disposal or further utilization. The separation of these inerts is important to protect the operating plant components from abrasion.

The suspension is then thickened through dewatering and then intermediately stored in a storage tank (suspension buffer). At this stage, the reaction process is already underway. Effectively, a pre-acidification of the fresh pulp (hydrolysis) occurs. In other words, the process resembles a two-stage process in that the suspension buffer acts like the first hydrolysis phase of a two stage reactor.

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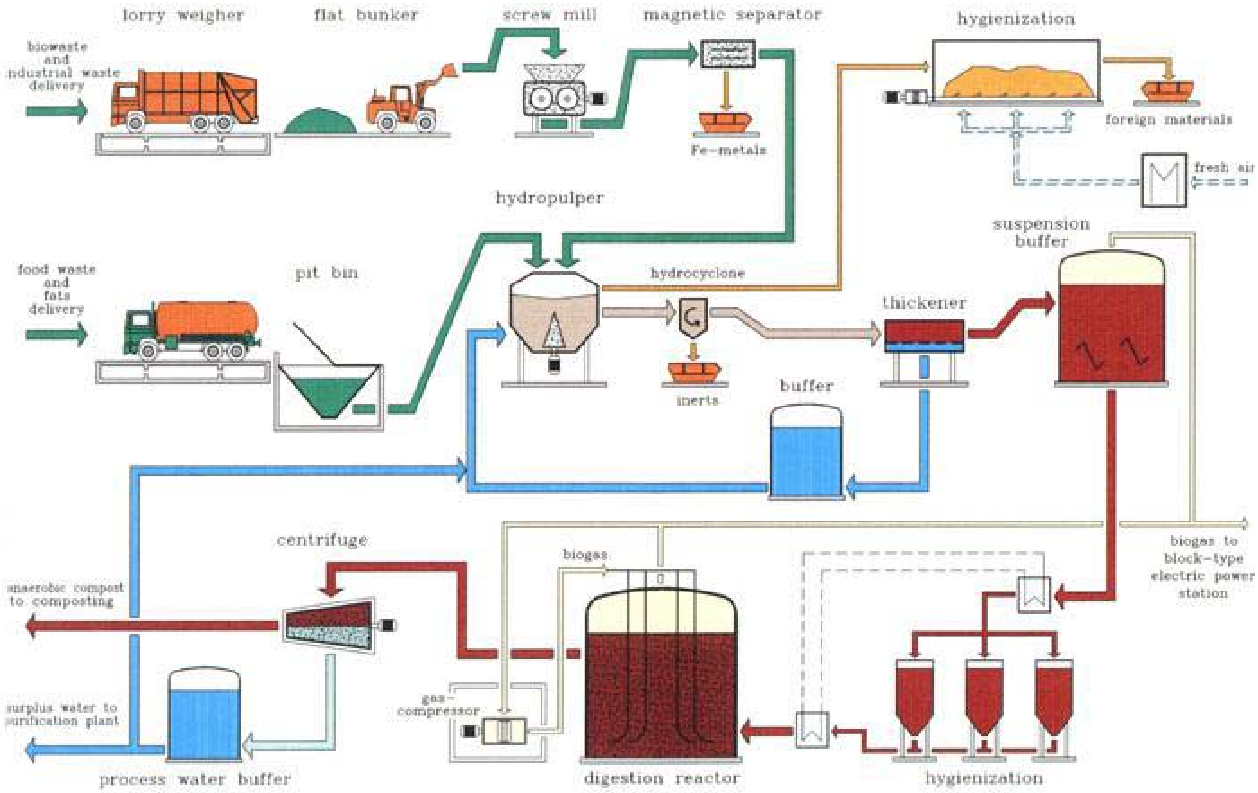
[33] Information concerning this plant is from BTA.

Figure 16: Schematic of Pseudo Two-stage Plant



Source: BTA

The pre-acidified pulp is then heated by means of a heat exchanger for more than one hour to a temperature above 70°C so it is sanitised. This is clearly significant in the UK context for reasons which will become clear in Section 9.3.1. The sanitised pulp, cooled by heat exchanger again, is pumped into the methane reactor for a mesophilic digestion. The retention time is two weeks and the pulp is continuously mixed in the reactor. The biogas produced, which rises to the liquid surface, is collected in a gas dome.

After the digestion process, a screw centrifuge separates the pulp into solid matter (digestion residue) and water. The dewatered digestate is fed to an aerobic post-composting stage, where it is converted by windrow composting within six weeks into a high-grade matured compost. After screening, matured compost is temporarily stored in windrows until it is picked up.

The water is fed back as process water to the process circulation. Surplus water is taken into the plant waste water treatment system, where it is cleaned before being pumped into a draining ditch.

The produced biogas is collected in the gas dome of the methane reactor and the suspension buffer and is fed into two CHP generators (combined heat and power generators) for its utilization as energy. The biogas, continuously converted into electrical energy and heat, meets the energy demand of the digestion plant itself, and surplus energy is fed into the public support system.

BTA reports a biogas generation of 90Nm^3 per tonne. This suggests a gross energy production of the order 100-150 kWh per tonne (methane content of biogas = 55%, 25% - 35% efficiency) and heat production of the order 220-260 kWh per tonne (methane content of biogas = 55%, 50% - 60% efficiency). Assuming internal energy use of the order 25 kWh of electricity per tonne, and 25 kWh per tonne of heat for steam generation, the net delivery would be of the order 75-125 kWh per tonne electricity and 195-235 kWh heat per tonne. These are estimates made in the absence of specific data for the plant.

7.4 Dry, Single-step, Thermophilic – Kompogas, Rumlang, Switzerland

In Switzerland, the 7.2 million inhabitants produce an average of 90kg of biowaste each year. Ever since 1986, the use on agricultural land of compost derived from mixed waste has been banned. Only separately collected waste can be used to make compost. Although in the nation as a whole, only 12% or so of the 641,400 tonnes processed are processed in digestion systems (the rest is composted aerobically), the figure rises to 30% in the Canton of Zurich, and it is anticipated to reach 40% this year (2004).[34]

In the Canton of Zürich, where several Kompogas plants have been built, over 100,000 tonnes of organic waste arise per year. Its main components are garden and kitchen waste, containing a high proportion of rotten fruit and vegetables, and organic waste from industry.

Picture from CADDET Technical Brochure 18: Electricity and Heat from Source-separated Organic Waste, IEA and OECD.

In the early 1990s, most biowaste was disposed of in incinerators or in large central composting plants. These disposal methods for biowastes were perceived as having the following disadvantages:

- incineration of biowastes is not desirable because of the high water content of the organic waste;
- composting plants are both extensive and labour intensive;
- expensive technical measures are necessary to avoid emission of odours and to dispose of waste water;
- composting requires inputs of energy, eg fuel oil and/or electricity;
- wet organic fractions, particularly of household origin, need to be mixed with large quantities of wood chips which could otherwise be used as fuel.

Kompogas plants operate with a one stage process in the thermophilic zone. Temperatures are maintained at 55-60°C. The plant accepts organic waste from households and industry. The biogas is either used on-site for electricity and heat production or converted into vehicle fuel. The residue is a high quality compost for use in horticulture and agriculture.

The Rumlang plant was essentially a demonstration project and has a capacity of 5,000 tonnes of organic waste per year.[35] The organic material delivered to the plant is collected in a receiving tank. From there it is moved to the sorting section, then to the shredder and finally to the storage tank by means of screw conveyors. The preheated, viscous organic material then enters a horizontal fermenter, in which the main process takes place over a period of 15 to 20 days. The biogas extracted passes through a treatment stage, is dried and delivered to a storage tank.

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[34] K, Schleiss, C. Fischer, J. Fuchs and U. Galli (2003) *Wider Benefits of Composting: A Survey of the Beneficial Effects of the Application of Compost and Digestate*, Paper presented to the ISWA Conference on The Biological Treatment of Waste and Its Role in Integrated Waste Management, Pollutec, Paris, 4-5 December 2003.

[35] Some of the information for this study is taken from *CADDET Technical Brochure 18: Electricity and Heat from Source-separated Organic Waste*, IEA and OECD.

Sufficient storage capacity is provided to guarantee a continuous supply to two cogenerators. Each cogenerator consists of a gas engine coupled to an electric generator. They convert approximately 1,300m^3 of biogas produced per day by the fermenter into 1,500 kWh of electricity and 3,600 kWh of net heating energy. Alternatively, the biogas can be upgraded to about 98% methane to be used as a fuel for motor vehicles.

The solid residue is dewatered in a screw press and delivered to a post-fermentation reactor where, in the presence of air, the final conversion to mature compost takes place. The whole process takes place in an enclosed building and the exhaust air passes through a biofilter to reduce odour and VOC emissions to the environment.

This plant has been in continuous operation since 1991 and has been unaffected by metereological and seasonal influences. No difficulties have been encountered in selling the compost, but marketing the surplus heat can be problematic. Partly to overcome this, tests were carried out on transport vehicles to evaluate the use of biogas as a fuel. Measurements have shown that 370,000 m^3 of biogas may be produced by the plant each year, equivalent to about 0.1 m^3 of gas per kg of organic waste. This is about the same quantity of gas given off by 1 kg of organic waste and it can fuel a car for about 1 km. Kompogas has used this as a marketing tool to encourage citizens to engage in source separation, and to recognize the potential for using low emissions vehicles run partly on gas from biowaste.

Table 10: Performance of Kompogas Plant

Annual capacity	5,000 tonnes organic waste
Biogas production (about 60% Methane)	1,300 m^3 per day
Fuel oil equivalent	800 litres
Electricity supplied to grid	1,500 kWh per day
Heating energy supplied to customers	3,600 kWh per day
On-site consumption and losses	2,700 kWh per day
Total energy production	7,800 kWh per day
Compost production	5.2 m^3 per day (25% of waste supplied)
Waste water	0 to 0.25 m^3 per day

The cost of the plant in Zürich were obtained in 1993 prices (where SFR is the Swiss franc). In Table 11, these have been converted to UK sterling at the 1993 rate and inflated at the UK inflator (the underlying inflation rate was used). The costs do not include any allowance for land acquisition.

Table 11: Costs for Kompogas Facilities from 1993,

Annual waste capacity	5,000 tonnes	UK Equivalent, (2003, per tonne)	10,000 tonnes	UK Equivalent, (2003, per tonne)
Total investment	SFR8.1 mn	£1.23 mn	SFR9.0 mn	£1.49 mn
Total running costs	SFR1.44 mn /year	£43.69	SFR1.92 mn /year	£29.23
Revenue from sale of electricity	SFR0.12 mn /year	£3.04	SFR0.22 mn /year	£3.34
Net running costs	SFR1.18 mn /year	£40.64	SFR1.66 mn /year	£25.89

Source: Data from Kompogas in Leif Wannholt (1999) Biological Treatment of Domestic Waste in Closed Plants in Europe - Plant Visit Reports, RVF Report 98:8, Malmo: RVF.

7.5 Wet, Mesophilic, Single Stage - Linde-KCA Co-digestion Plant, Saxony, Germany

Co-digestion enables synergetic effects in anaerobic bacterial metabolism, energy yield, and residual solids handling to occur. Other benefits are reduced costs in terms of licensing / approvals procedures and more efficient operation. Some of the expected advantages of such a plant can be assessed through reference to the plant in Radeberg, located at Saxony, Germany. Here, co-digestion of municipal sewage sludge, source-separated organic household wastes, and organic residues from food production industries in the area takes place.

7.5.1 Goals and Objectives of the Plant Concept

The main sewer of the Saxonian town Radeberg, Germany, empties into the small river "Obere Röder". From the seventies through to the nineties, the waste load was only reduced by mechanical treatment and additional sludge stabilization in an open anaerobic pond. To meet tighter discharge limits introduced in the middle of the nineties, the waste water treatment association with responsibility for treatment decided to upgrade the plant to a state of the art facility of capacity of 100.000 Person Equivalents, including activated sludge process and anaerobic digestion of primary and surplus sludge.

The principal objective of introducing sludge *digestion* was to achieve self-sufficiency in energy generation (heat and power) for the wastewater purification complex through co-generation. Because of the low biogas yield from sewage sludge the objective could only be reached by adding carbon-rich organic wastes to the sludge for higher biogas production. An operations company was founded in which the WWT Association and the local biowaste collection company were shareholders. This made possible the co-fermentation of sewage sludge and source-separated municipal bio-waste, as well as residual organic fractions from local food production industries.

Not only has this resulted in the required higher biogas production but it has also led to cost reduction for the waste water and biowaste treatment in the form of numerous synergetic effects as summarized in Box 1.

Box 1: Synergetic effects of the co-fermentation of sludge and waste at the location of the sewage treatment plant

Simplified approval planning for the location that has been approved already according to the Law on Water.
Use of the existing infrastructure of the sewage treatment plant for waste treatment and joint maintenance, alert, etc.
Considerably reduced investment costs for the co-fermentation concept compared with separate solutions for sewage sludge digestion and biowaste fermentation

- no separate process water treatment plant required;
- greater part of the process stages for sewage sludge treatment (digestion, gas utilization, dewatering) need only be extended in size or by modular additions

Higher biogas yield from sewage sludge through more intensive degradation (sludge minimization) as a result of the co-fermentation with waste
Considerably reduced operating costs due to co-fermentation

- higher biogas yield has positive effect on energy balance of sewage treatment plant;
- lower organic flocculant usage for dewatering

Use of the purified wastewater of the sewage treatment plant as cooling water (CHP station) and process water for pulping (avoiding salt load increase)
Upgrading (reduction of heavy-metal load, etc.) and better acceptance of dewatered fermentation residue from the co-fermentation plant compared with pure sewage sludge
Higher degree of dewatering for fermentation residue due to structure containing waste compared with dewatering in sewage treatment plant only (better suitability for digestion).

The schedule of project development and plant realization illustrates the short period of time available and the demands on all the companies included. The following processes occurred between 1996 and April 1999:

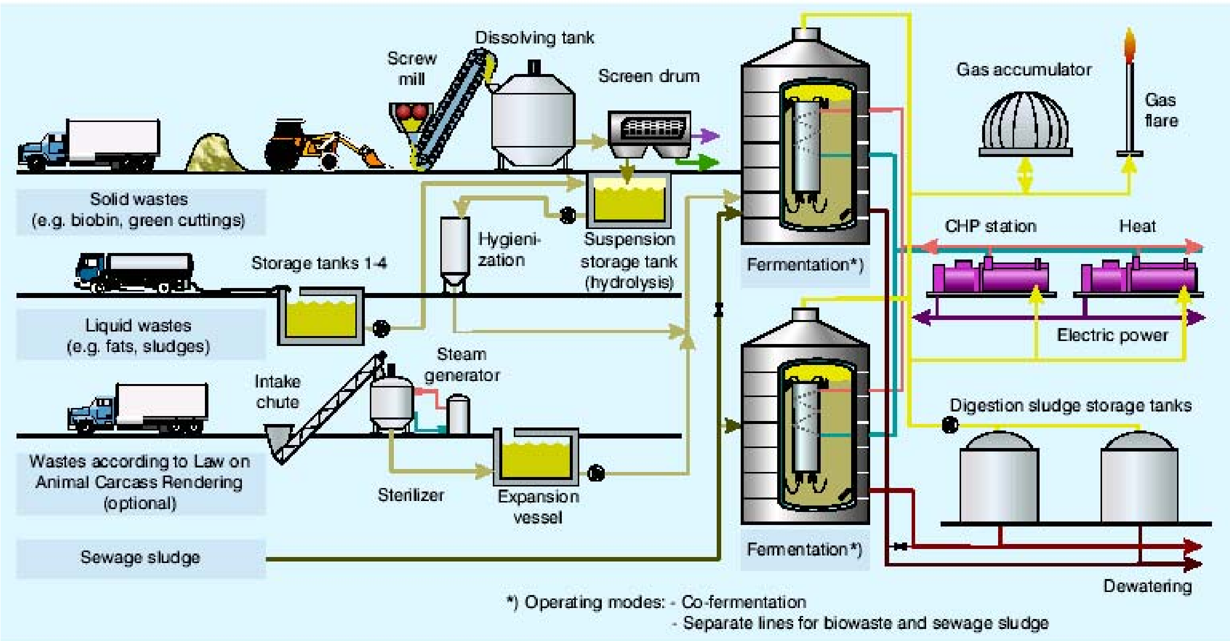
1. cost benefit analysis
2. analysis of economic efficiency
3. planning, tender, and assigning to the general contractor 1997
4. plant realization 1998
5. commissioning and start-up 04/1999
6. accompanying process research for optimization and long-time adaptation

7.5.2 Technological Plant Description

The flow diagram of the process presents the actual stage of realization for the co-fermentation plant (Figure 17).

Table 12 gives an overview of equipment capacities as well as main process parameters as designed on the basis of the tender document. The extended pictogram shows the planning of a second conditioning line for organic wastes to be handled under the requirements of the German law for animal carcass rendering/animal waste processing (sterilization at 133 °C for at least 20 min). Space and technological interfaces for a future installation of that process step have already been prepared in the realized plant. However it remains to be seen what consequences will come from the actual debate on the future of livestock breeding and animal waste processing as well as disposal of final products.

Figure 17: Schematic of the Linde Co-digestion Plant in Saxony



Source: Linde KCA

One step in the direction towards increased hygiene in the present process is the examination of technological consequences for change over from mesophilic to thermophilic digester operation. The plant views presented in the appendix, as well as the press comments to the plant opening, give further details about the installed main equipment and about the active interest of the residents in the region.

Table 12: Plant and process parameters

Waste treatment and conditioning	
Crushing with low speed screw mill	6 t/h
Mashing with pulper	16 m³
Reject separation (magnetic iron separator, sediment separation devices, rotating drum sieve)	30 m³/h
Biowaste sludge buffer and hydrolysing tank (underground)	
Bio-sludge sanitation	
Sanitising unit for charge wise treatment at 70°C for one hour with two tanks of 12 m³	
Heat recovery with spiral heat exchangers	
Digestion	
Two LINDE - Digesters with internal loop mixing device	2 x 2 300 m³
Two effluent storage tanks as sludge buffer previous to sludge dewatering	2 x 350 m³
Gas system	
Gas holder (double-shell plastic-coated textile type)	780 m³
Flare (closed burning chamber type)	
Gas usage	
Nominal biogas production	2 500 000 m³/year
Two co-generation units (CHP) with	2 x 380 kW electric power
	2 x 550 kW thermal power
Biogas-heated boiler	335 kW
Balances and yield rates	
Nominal hydraulic retention time	20 days
Organic digester load	2.5 kg/(m³.d)
Volatile solids turnover	40 to 60 percent
Specific biogas production (related to sum of total input)	40 m³ (NTP)/t
Methane content in biogas	about 63 percent by Vol.
H2S	< 100 ppm
Dewatered digested residues (decanter centrifuge) with 28 percent of TS	11 400 t/year

7.5.3 Locational Advantages

The synergistic effects of a co-digestion plant for sewage sludge and biowaste integrated into the site of the wastewater purification complex are extensive. There are reduced costs for planning and of obtaining site approval by the relevant authority, as well as reductions associated with mutual use of utility connections, social facilities, office buildings and workshops etc. Technological components like digesters, decanter centrifuges for sludge dewatering, and the biogas system with CHP station are also necessary for separate sludge and waste treatment plant. These facilities have only to be adapted to the higher capacity of a co-digestion plant. Staff requirements and all efforts for company management are relatively scale independent in the relevant range of operation and the expense for a separate additional plant can be saved. This is why the operating company sees the advantages as being so significant for both fields of disposal, i.e. water and waste, respectively. Clearly, local conditions as well as the relevant laws pertaining in different situations play an important role in determining the actual effects and have to be investigated in detail.

7.5.4 Operational Experiences

A well-known problem of the production of a pumpable slurry from bulk biowastes is the resulting layers of scum and sediments in the buffered pulp, that results from the continuous substrate hydrolyzation, which reduces the sludge viscosity and enables inert particles with smaller and smaller grain diameter to sediment. On the other hand hydrolysis gases (mainly CO_2, H_2S, small amounts of

CH_4) are emitted and make suspended organic sludge particles float. Only through the use of special equipment can the decomposition be hindered, so ensuring a stable sludge quality for digester feeding.

The mechanical / hydraulic conditioning of the incoming bulk biowastes results in a fraction of removed inert material (stones, sand; parts of glass, ceramics, bricks, concrete etc.) which are further contaminated with smaller amounts of organic matter (VS-analysis). That makes it difficult to find an appropriate disposal route and is an additional cost factor. To clean this fraction, the use of the sand scrubber of the wastewater treatment plant was tested, and with good results. A quality was reached for use as base additive in for instance road construction.

Biogas yields were tested for relevant waste fractions including possible mono-charges like citrus peelings, etc. as well as the digestibility of biodegradable plastic bags for a new generation of waste collection service. Special efforts are directed to the biogas quality with respect to its energetic use in gas engines (CHP). Biowaste digestion is well known for the rather high H_2S-content in the biogas. But strong reduction is guaranteed by biochemical suppression of H_2S production in the Linde digester, with the help of air injection.

Additional reduction takes place at the Radeberg plant because of a form of precipitation similar to that of ferrous sulphide. This happens because the municipal surplus sludge is flocked with ferrous chloride, which enters the digesters in small amounts via the sludge feeding. That combination of biological and chemical factors reduces the H_2S in the biogas to a range of $10 < H_2S < 100$ ppm which is much lower, than the limits for gas motors claimed by many other suppliers, and well within flue-gas concentrations stipulated by German law.

Biogas from sewage sludge digestion is mostly contaminated with Siloxanes resulting from silicon compounds in the waste water (from household chemicals and cosmetics). They are very dangerous for gas engines, where they are oxidized and built up as hard layers in the cylinder bores, which can severely damage the engine. Analysis was carried out for the leading components with resulting concentrations below the value of 17 mg/m³ discussed as critical for gas engines. Of course these analyses must be repeated in intervals because with changing chemical compositions of the relevant input materials as well as different residents´ habits the results can vary over the years.

7.6 Wet, Single-step, Mesophilic – BTA, Hogl, Germany

This plant commenced operation in August 1995. In January 1997, the plant was extended through the addition of an additional treatment step including the hygienisation of food waste. Today, the plant treats 17,000 t/a biowaste/commercial waste.

Following delivery of the material, the biowaste is temporarily stored in a flat reception bay and then transported by a front loader into a screw mill, where it is roughly disintegrated. A conveyor belt moves the disintegrated biowaste into a dissolution tank (pulper) with a volume of 20 m^3, which is connected to an air cleaning system. In the pulper the biowaste is mixed with process water and agitated intensively.

Due to the specific flow conditions inside the pulper, the organic components of the biowaste are disintegrated and dissolved in the water. Floating materials such as plastics, textiles, or wood are removed using a rake. Glass, metals, stones, bones and other heavy materials are removed by a lock system. The result is a thickened suspension (pulp), more or less completely free of undegradable materials. The pulp is intermediately stored in a surgetank, which is also filled with the pulping products of the second line (food waste). The surgetank is connected to the air cleaning system too.

Picture courtesy of BTA

For the treatment and sanitizing of food waste a second line with a further pulper (8 m^3) is now available. Besides the contaminant this provides, this also makes possible a pasteurisation at 70^o C. The delivered food waste is intermediately stored in a closed bunker. Disintegration and transport into the pulper is achieved using a conveyor screw. The pulper, as well as the bunker and conveyor screw are connected to the air cleaning system.

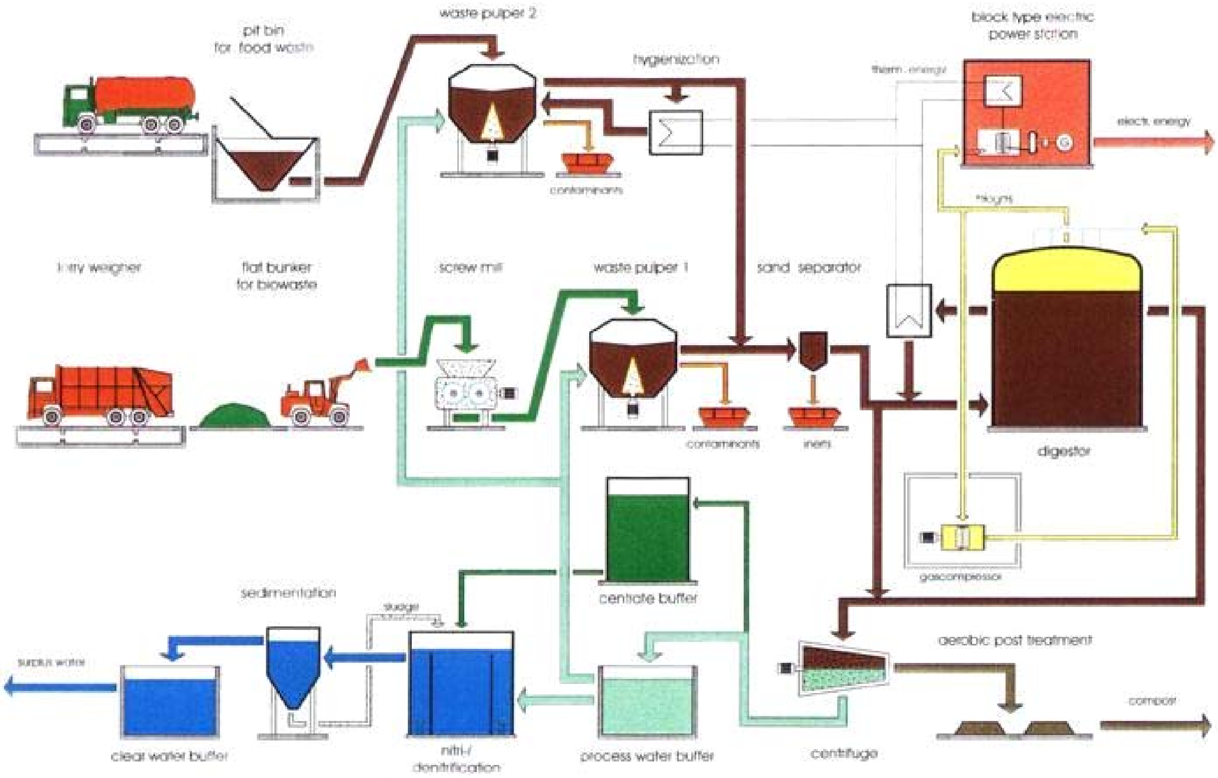
After pasteurisation for a minimum of 30 minutes the pulp is transferred into the above mentioned surgetank through a sieve installed at the pulper bottom. This sieve assures the necessary degree of disintegration of the pasteurized pulp. Rough contaminants are separated out of the pulper by rake after the hygienisation procedure. Heavy materials, which are retracted by the sieve at the pulper bottom are discharged by a heavy fraction trap. The pulp of both - the first and the second lines is then mixed in the surgetank and is passed through the connected grit removal system (hydrocyclone) for the removal of the finest inerts like glass splinters or grit. This hydrocyclone process removes the smaller inerts, so reducing the chances of wear and tear caused by abrasion. The cleaned pulp is then pumped back into the tank.

The methane reactor is fed from this surgetank. The pulp remains for approximately 14 days in the reactor, which is a steel made tank with a volume of 20 m^3. The reactor content is continuously mixed by compressed biogas (extracted from the tank). The organic components are decomposed in an anaerobic medium and transformed into biogas. CHP stations transform the gas into electricity and heat. The energy generated is used to provide process energy for the plant with the surplus electricity being fed into the public supply system. Surplus heat energy is given to the connected farm, or is passed into the environment after passing through an air cooling system.

The digested pulp is dewatered using a centrifuge and the solid digestion residue is transferred to a composting bay, where it is transformed into high quality compost in a short aerobic post-treatment. In this composting step, the dewatered digestate is mixed together with green waste to provide structural material for the aerobic process. The cleaning of the liquor is carried out under aerobic conditions, and consists of a nitrification-denitrification step. The cleaned water is stored in an open tank and can be reused as process water in the pulping process. Surplus water is transported to a municipal sewage water plant.

A schematic of the plant is shown in Figure 18 below.

Figure 18: Schematic of BTA Plant in Hogl



Source: BTA

7.7 Summary

These case studies give some idea of the nature of technologies in use, but only hint at the range of potential applications. It would have been possible here to have provided details of case studies on co-digestion with agricultural wastes. However, we chose not to do this since the majority of such plants accept only small proportions of municipal wastes. This is not to say that such facilities are not relevant for the Northern Ireland context. It merely reflects the focus of this study.

There is a growing literature available on AD plants. Case studies are now available from many different nations, and using many different technologies. Confidence that the process is reliable for dealing with municipal waste, both source-separated, or separated fractions from residual waste, is growing. This is reflected in the growth in the number of plants installed across the EU.

8.0 REVIEW OF LEGISLATION ON WASTE TREATMENT AND THE FATE OF END PRODUCTS

The waste management industry in Northern Ireland is in the throes of what must be seen as the early days of an enormous upheaval. Municipal wastes, and in particular, biodegradable municipal wastes, have fallen under the spotlight because EU legislation (the Landfill Directive) has established targets for Member States which are set in terms of requirements to reduce the amount of biodegradable municipal waste sent to landfill. The UK approach to these targets set by the EU has been based around two elements:

1. A tax on landfilling; and, more significantly,
2. A system of tradable permits designed to ensure that within the UK, only the amount of biodegradable waste which EU legislation allows can be landfilled.

These mechanisms are both designed to drive material away from landfill. They do not specify the route to which it is expected the remaining material should go.

However, a number of signals suggest that the preferred route is source-separation of materials for recycling and either anaerobic digestion or (in fact, sometimes it will be 'and') composting:

1. At the EU level, since the late 1990s, the interpretation of the waste management hierarchy (as set out in the Waste Framework Directive) implied by a Commission Communication arising from a waste management strategy review, endorsed by the European Parliament in a resolution of 1997, clearly places recovery of material above recovery of energy. It stated:
   'Within the recovery principle, where environmentally sound, preference should be given to the recovery of material over energy recovery operations. This reflects the greater effect on the prevention of waste produced by material recovery rather than by energy recovery' (author's emphasis).

   The UK interpretation of the hierarchy appears to be slowly aligning itself with this view. This was illustrated in the strategy for England and Wales, *A Way With Waste*, where it was suggested that recycling and composting should be given qualified preference over energy recovery. More recently, in the Strategy Unit Report, *Waste Not Want Not,* the distinction was made between 'high-in-hierarchy' options (materials recovery, re-use and minimisation) and those generally related to residual waste (energy recovery and disposal). This reading of the hierarchy – in which materials recovery lies above energy recovery – has been given some further support as a consequence of recent rulings in the European Courts (under which dedicated 'energy from waste' plants are to be viewed as 'disposal' and not recovery);

2. In the late 1990s, the European Commission began a process designed to lead to the development of a Directive on Composting (Directives are now in existence with respect to Landfill and Incineration, and several Directives, the number of which is growing, make demands for the recovery of specific materials). This has led to two Drafts of a Biowaste Directive, which (if implemented in its latest form) would mandate the source separation of biodegradable wastes for anaerobic digestion and / or composting. The Draft Directives also made clear that biological treatment of residual wastes, when carried out to specified standards, would be considered sufficient such that the residue would not be considered as 'biodegradable' for the purpose of the targets specified under Article 5(2) of the Landfill Directive. In short, these Draft Directives made it clear that for all biodegradable wastes from the municipal stream, including those from hotels, restaurants, etc., the preferred treatment would be biological treatment. The development of the Biowaste Directive came to something of a halt after the Second Draft. However, new life has been breathed into this Directive by virtue of the European

Commission's Communication to the Council and the Parliament *'Towards a Thematic Strategy for Soil Protection'*. This states
By the end of 2004 a directive on compost and other biowaste will be prepared with the aim to control potential contamination and to encourage the use of certified compost.

The pre-amble to the recent *'Regulation of the European Parliament and of the Council laying down health rules concerning animal by-products not intended for human consumption'* also states:

the Commission has given a commitment that by the end of the year 2004 a Directive on biowaste, including catering waste, will be prepared with the aim of establishing rules on safe use, recovery, recycling and disposal of this waste and of controlling potential contamination.

Most recently, a Discussion Document has been issued by the European Commission concerning Biowastes and Sludges. This reflects the intention to bring together negotiations concerning Directives on Sludge and the Biological Treatment of Biodegradable Waste, both of which were referred to in the Communication "*Toward a Thematic Strategy on soil protection*" (COM(2002) 179).

3. Finally, in Northern Ireland, the National Waste Management Strategy sets targets for the recycling and composting of waste. The key recycling / composting target is 25% by 2010, though the recovery target is 40% (and as a consequence of decisions taken in the European Court of Justice, it is possible that under new definitions, dedicated energy-from-waste plants would not be classified as recovery). A consultation paper on the trading of landfill allowances has been issued (and consultation will run to April 2004). In addition, the Northern Ireland Strategy is under review, and will be informed by the Consultation. Lastly, a Biodegradable Waste Strategy, which was issued in Draft as a status report, will be completed this year (and will also be subject to consultation).

Notwithstanding these drivers, progress in developing capacity for processing biowastes, separately collected or otherwise, has been slow (and this applies not only to Northern Ireland, but to other parts of the UK). There are probably a range of reasons for this, not least of which has been a less developed knowledge of the processes involved. However, legislation and regulation has been less than supportive of these technologies. In what follows, a number of relevant pieces of legislation and regulations are assessed to understand their impact upon biological treatments. A separate chapter is given over to the discussion concerning the Animal By-products Regulation.

8.1 Definitions Regarding 'Composting'

8.1.1 The Definitional Vacuum

What is composting? The answer to this question usually elicits a response to the effect that it is the aerobic biodegradation of material, or some similar definition. This is fine (or can be made so) from the perspective of the biological process which a material may undergo. But the answer makes no reference to the end product which emerges following the process. There are no legal definitions of compost in the UK. One of the consequences of this is that it remains unclear what conditions need to apply before one can consider the material which emerges from 'a composting process' (or for that matter, any other) to be eligible for spreading on land as 'compost' (and when, on the contrary, it may have to be considered, still, as a waste).

Why is this important? The DETR Report of the Composting Development Group on the Development and Expansion of Markets for Compost defined compost as:

> *'Biodegradable municipal waste which has been aerobically processed to form a stable, granular material containing valuable organic matter and plant nutrients which, when applied to land, can improve the soil structure, enrich the nutrient content of soil and enhance its biological activity.'*

In developing voluntary quality standard for compost producers, the Composting Association defined compost as:

> *'Material that has been subjected to controlled, self-heating biodegradation under aerobic conditions and stabilized such that it is not attractive to vermin, does not have an obnoxious odour and does not support the regrowth of pathogens and their indicator species. Compost that has been subject to a screening process may be classified in terms of its particle size grade, from fine to coarse.'*

In the standard being developed by WRAP, the PAS (Publicly Available Specification) 100, compost is defined as:[36]

> *Solid particulate matter that is the result of composting, that has been sanitized and stabilized and that confers beneficial effects when added to soil and / or used in conjunction with plants.*

In turn, composting is defined as:

> *Process of controlled biological decomposition of biodegradable materials under managed conditions that are predominantly aerobic and that allow development of thermophilic temperatures as a result of biologically produced heat, in order to achieve a compost that is sanitary and stable.*

It is important to understand the lack of distinction that these definitions imply between composts which meet quality standards, and materials which meet the stated definition, but which do not meet other criteria laid down in standards such as the PAS 100, or in the Second Draft of the Biowaste Directive. The PAS 100 has, at present, a status which is ambiguous. It seeks to establish a standard for compost, but Best Value definitions of 'compost' (see below) do not require such a standard to be met.

One can understand that a clear aim of standards is to differentiate products resulting from approved processes, and which meet the stated criteria, from those which do not. This suggests a need either to define compost more accurately in legislation (distinguishing 'composts' from 'wastes'), or establishing statutory or quasi-statutory standards which differentiate across 'types of compost'. The problem in the UK at present is that a standard is developing – the PAS100 – but as yet, it has no statutory, or even quasi-statutory status, so in turn, no one *has to* meet it unless customers demand that they do. Best Value targets in England make no reference to the standard. Having said that, to the extent that the PAS100 seems likely to become a British Standard, this ought to add some clarity to the issue since it will set a standard for 'composted materials'.

8.2 Is Digestion an Energy Recovery Operation, or a Material Recovery Operation?

It should be noted that all of the above discussion has focussed on composting, and not anaerobic processes. The same issue of whether or not materials could be applied to land applies to anaerobic processes too. However, there are other important issues which have affected the view of (and potential for uptake of) anaerobic digestion:

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[36] BSI, WRAP and Composting Association (2002) *PAS 100: Specification for Composted Materials*, London: British Standards Institute.

a) whether or not local authorities are likely to see source-separation as necessary (or not) in order to achieve targets for 'recycling and composting'. This relates to the issue of product standards discussed above; and

b) whether local authorities are likely to see digestion as an attractive route for dealing with biowastes (source-separated or otherwise).

The latter issue raises questions as to how anaerobic digestion fits into definitions of 'composting' as defined for the purposes of the relevant national / local authority targets.

As discussed above, there is no statutory definition of composting. Still less is there a definition of 'digestion'. However, it is quite clear that anaerobic digestion has, at least until recently, been perceived by the Environment Agency and others as an energy *recovery* technique, rather than a materials recovery (recycling) process. Hence, it is quite normal for Local Authority strategies and Waste Plans to discuss 'composting' without mentioning anaerobic digestion, the discussion of which is left to sections on 'energy from waste'.

Significantly, until recently, the English Best Value definitions, which are intended for use in the measurement of performance of local authorities in their provision of waste management services, defined 'composting' as follows:

> *'Composted' means, the controlled biological decomposition and stabilisation of organic substrates, <u>under conditions that are predominantly aerobic and that allow the development of thermophilic temperatures as a result of biologically produced heat</u>. It results in a final product that has been sanitised and stabilised, is high in humic substances and can be used as a soil improver, as an ingredient in growing media, or blended to produce a top soil that will meet British Standard BS 3882, incorporating amendment No 1. In the case of vermicomposting these thermophilic temperatures can be foregone at the point the worms are introduced. (our emphasis)*

Two things are worthy of note:

a) The definition was clearly a definition of an aerobic process; and

b) There was not much to guide the 'composter' as to whether the quality of the end-product, in terms of physical contaminants, etc., was deemed to be of great significance.

This definition clearly excludes the anaerobic treatment of biowastes, however good the quality of the resulting digestate might be. This seems highly irregular. At one extreme, one could take wastes of dubious provenance, compost them aerobically, and spread the resulting material on land without much regard for long-term soil health. This would count towards a recycling / composting target. On the other hand, once could have digested a well-separated fraction, generated energy in the process, and irrespective of the quality of digestate, this would not count towards a recycling / composting target. This seems odd to say the least.

Recognising the contradictions in this position, Defra recently issued a paper for *'Consultation on the Role of Anaerobic Digestion of Municipal Waste within the Best Value Performance Standards'*. The thrust of the document was to discover the best way for integrating anaerobic digestion into the Best Value regime. The outcome of the consultation has been to amend Best Value definitions so that in England, recycling and composting targets now include treatment by AD. AD is defined (for these purposes) in the following way:

> *"Anaerobic digestion " means, the biological decomposition and stabilisation of organic substrates in the absence of oxygen and under controlled conditions in order to produce biogas and a digestate. It results, either directly or after subsequent aerobic treatment, in a final product that has been sanitised and can be used as a soil improver, as an ingredient in growing media, or blended to produce a top soil that will meet British Standard BS 3882, incorporating amendment*

> *No 1. […] Where the treatment involves anaerobic digestion followed by composting (or vice versa) the tonnage is based on the quantity entering the first biological process.*

There is still no clear link between quality standards for the materials from digestion, so the vacuum remains in terms of the quality of materials from the process. However, at least in England, recognition that AD can be equivalent to composting for the purposes of waste management targets is welcome for the development of AD for source separated biowastes.

8.3 The Waste Management Licensing Regulations;

The UK implements the Waste Framework Directive through the Waste Management Licensing Regulations 1994 (as amended) (WMLR). This includes the specification of a range of activities – defined as 'recovery' - for which Exemptions from Licensing may be claimed (these are specified under Schedule 3 of the WMLR).

The significance of the WMLR lies in the fact that the lack of clear definitions in the UK as to what compost actually is suggests that there will inevitably be concerns regarding which materials can be applied safely to land when the definitions of compost in existence do not delineate between materials which can and cannot be safely applied to land. Indeed, it is not obvious when, or under what conditions, a material which has been through a composting process ceases to be a waste (or indeed, if such a process is possible).

Consequently, the exemptions under Schedule 3 of the WMLR, some of which allow the application of wastes to land as long as there is no harm to human health or the environment, lack specificity. There is no clear link to statutory standards (which, in any case, do not exist), or even to a definition of compost through reference to a process. If, for example, it makes sense to distinguish between 'wastes' and 'composts' on the basis of enabling the use of the latter to occur freely, and without restrictions, the rationale for allowing 'wastes' to be applied to land without licensing in the absence of such a clear distinction would appear to be somewhat foolish (it is certainly not likely to give adequate protection to soil quality). If a distinction is to be drawn between 'wastes' and 'composts' on the basis of the lack of a need for regulation of the latter, it is simply inconsistent to suggest that 'wastes' should be applied without licensing unless specific (additional) restrictions are applied.

It is notable that the exemption from licensing under Paragraph 7 of Schedule 3 specifies a range of materials which can be spread on land under certain conditions. These include 'compost', suggesting that (though compost is not defined) material which is called 'compost' is itself a waste, at least as far as the WMLR are concerned. This suggests, implicitly, that compost should be subject to the same rules as other waste materials, raising all sorts of questions as to if, how, when and why it ought to be acceptable to spread compost on land unencumbered by waste-related legislation. Effectively, the WMLR's fall-back position is found in Paragraph 4 (1)(a) of Part 1 of Schedule 4 of the WMLR:

> ***4.*** *(1) For the purpose of this Schedule, the following objectives are relevant objectives in relation to the disposal or recovery of waste-*
> *a) ensuring that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment and in particular without-*
> *i) risk to water, air, soil, plants or animals; or*
> *ii) causing nuisance through noise or odours; or*
> *iii) adversely affecting the countryside or places of special interest;*
> *b) implementing, so far as material, any plans made under the plan-making provisions.*

This is unlikely to provide the necessary safeguards required to protect soil quality. At best, it is simply far too open to interpretation.

8.4 The PAS 100 Standard for Compost

The Waste and Resource Action Programme (WRAP) has been developing a standard for composted products. This builds on earlier work by the Composting Association, which developed a voluntary standard for compost. The PAS 100 – a Publicly Available Specification – is a step on the way to the development of a fully fledged British Standard. As far as process standards for sanitization are concerned, the PAS 100 recommends the standards in Table 13 below. However, it also makes clear that legislation as laid down in the Animal By-products Regulation (ABPR) would take precedence over any process standards set out in the PAS. Hence, since the emergence of the ABPR, these have been more or less irrelevant (though they make for interesting comparisons).

Table 13: Recommended Minimum Conditions for Sanitization of Input Materials

System Type	Minimum Duration	Minimum Temperature	Minimum Turning or Mixing
Windrow	14 days	⩾ 55°C in the core zone of the composting mass, except during turning / mixing if minimum temperature is regained within 24 hours, as far as can be practically ascertained or deduced	Five times during 14 days
	7 days	⩾ 65°C in the core zone of the composting mass, except during turning / mixing if minimum temperature is regained within 24 hours, as far as can be practically ascertained or deduced	Twice during 7 days
In-vessel	2 days	⩾ 60°C in all appropriate zones of the composting mass concurrently within an overall period of treatment, typically less than 5 days. No restriction on particle size.	Optional
	1 hour	⩾ 70°C in all appropriate zones of the composting mass concurrently within an overall period of treatment, typically less than 5 days. Particle size ⩽ 12mm.	n/a
Aerated static pile with insulating layer	7 days	⩾ 60°C in all zones of the composting mass, as far as can be practically ascertained or deduced	n/a

As far as the quality of end products is concerned, some of the key standards are as in Table 14 below. As far as municipal wastes are concerned, these standards are extremely difficult to meet if the feedstock is not source-separated biowaste.[37] See also Section 11.9.2.2 below.

8.5 Legislation Pertaining to the Application of Mineral Nutrients to Agricultural Soils

The standard for compost produced by The Composting Association, which preceded the PAS 100, included a recommendation that application or use should be conducted in accordance with relevant Codes of Practice and statutory regulations. Some of these are outlined below.

[37] See Dominic Hogg, Josef Barth, Enzo Favoino, Massimo Centemero, Valentina Caimi, Florian Amlinger, Ward Devliegher, Will Brinton and Susan Antler (2002) *Comparison of Compost Standards Within the EU, North America and Australasia*, Final Report to WRAP, 2002.

Table 14: PAS 100 Product Standards

Element	**Upper Limit (mg/kg dry matter, unless stated)**
Cadmium	1.5
Chromium	100
Copper	200
Lead	200
Mercury	1
Nickel	50
Zinc	400
Indicator Organisms	
Salmonella spp	Absent in 25g sample
Escherichia coli	Less than 1000 CFU (colony forming units) per gram
Physical Impurities	
Glass, metal and plastic	Maximum 0.5% by mass of total air dried sample (plastic must be no more than 0.25%)
Stones and other consolidated mineral contaminants >2mm	Maximum 7% by mass of total air dried sample
Weed propagules	Maximum 5 per litre

8.5.1 Code of Good Agricultural Practice for the Protection of Water (1998)

The Codes for Good Agricultural Practice were developed by MAFF as a guide to help farmers and growers avoid causing pollution, in this case specifically to water. It was originally intended that they would be introduced as a statutory code under section 116 of the Water Act 1989, which states that it is an offence to discharge polluting material into controlled waters without 'proper authority' ie consent from the (then) NRA under Section 108 of the Water Act. This includes all coastal or inland waters and groundwater. However, this status has not been realised so it remains a voluntary code. Hence, it is not automatically considered an offence to fail to adhere to it, and following the Code does not protect against prosecution, but in the case of a pollution incident the fact that the Code has been followed would be taken into consideration. It is recommended that water samples are taken frequently to identify potential problems early. Any polluters identified are fined.

The Code covers waste material added to land that is legislated through the Environmental Protection Act 1990. Organic wastes produced by the farm, such as animal manure, can be spread on the land, other wastes are controlled under the Environmental Protection Act but may be exempted provided that they fertilise or otherwise beneficially condition the land (this effectively links the Code and the WMLR discussed above).

The Code details best practice for application of material to agricultural land, focusing mainly on total nitrogen (N) supplied. Growers are advised to tailor N inputs to specific crop requirements and are referred to the MAFF Reference Book 209 "*Fertiliser Recommendations for Agricultural and Horticultural Crops*" for guidance.

An assumption is made that only a portion of the N in the ameliorant is available to plants in the first growing season following its application but nevertheless application rates are limited. In most cases a maximum total of $250kgNha^{-1}yr^{-1}$ is advised in any bulky organic material added, regardless of exactly how much is accessible to plants or susceptible to leaching. This may be lower in sensitive catchments.

However, in less sensitive areas up to 500 $kgNha^{-1}$ may be applied as organic waste in one application every two years. Paragraph 32 of the Code states:

> *In catchments less sensitive to nitrate leaching, some non-livestock wastes such as sewage sludge cake or composted organic waste which contain very little plant available nitrogen may be applied at rates supplying up to 500 kg/ha of 'total nitrogen' in one application every 2 years.*

The available portion is stated as being between 10% and 90% of the total N, which should be taken into account when calculating crop requirements, but there is no requirement to limit application according to this. Crop requirements in excess of the available amount have to be applied by other means. It is also stated that note should be taken of the phosphorus (P) content: in some cases fields should receive less than the stated amount of N in order to avoid inappropriate enrichment of the soil in terms of phosphorus. In order to comply with the Code it is therefore necessary to know the total N content of the ameliorant.

In Nitrate Vulnerable Zones (NVZs), the situation is slightly tighter. The Nitrates Directive provides for some discretion over the content of Action Programmes but there are certain measures which must be included. There are four key aspects to the measures:

1. Limit inorganic nitrogen fertiliser application to crop requirements, after allowing fully for residues in the soil and other sources.

2. Limit organic manure applications to 210kg of total nitrogen per hectare per year on arable fields (reducing to 170kg after four years) and 250kg of total nitrogen per hectare per year on grassland.

3. On sandy or shallow soils, ensure adequate slurry storage capacity for annual closed periods during which applying of some types of manure (slurries, poultry manures, liquid-digested sewage sludge) to land is prohibited. These dates are 1 September to 1 November (grassland or autumn sown crop) or 1 August to 1 November (arable without autumn sown crop) inclusive.

4. Keep adequate farm records, including cropping, livestock numbers and the use of organic manures and nitrogen fertilisers.

All farmers within the NVZs have been required to implement these measures since 19 December 2002.

Farmers located within the existing NVZs designated in 1996 have been required to adhere to a lower limit of 170 kg/ha total N per year for spreading manure on arable land since 19 December 2002. From 19 December 2006, farmers located in the new NVZs will also be required to adhere to this lower limit.

Information and guidance that refers specifically to compost is very limited. It must be noted, however, that farmers wishing to use compost as part of their fertilising or soil management regime may look to the guidance laid out in the Code. Application of compost in this expanding potential area of use may therefore be limited by criteria set down in it.

As far as digestate is concerned, the key issues relate to whether or not operators should seek to separate out digestate and fibre, and if so, why? One of the advantages of not separating out digestate into solid and liquid fractions is that there is less need for waste water treatment. However, the drawback of this approach is that the material is more likely to be phytotoxic. The fact that material is not stable means that the continuing demand for oxygen of the material may be problematic.

It is considered good practice to stabilise a separated solid fraction through aerobic composting before applying it to land. A liquid fertilizer may also result from the separation process.

8.5.2 Code of Good Agricultural Practice for the Protection of Soil (1998)

This Code complements the one for the protection of water. It was developed as a voluntary guide to help farmers and growers avoid long-term damage to their soils and contains guidance for maintaining soils for plant growth. As in the Water Code it states that additions should beneficially condition the soil in the long term and notes that organic manures can be a useful source of trace elements and the application of composted materials can lead to an increase in earthworm population, which is of benefit to the soil. Although the addition of sewage sludge to the soil could be said to confer long-term benefits, its use is controlled separately under the Sludge (Use in Agriculture) Regulations 1989, which is the UK implementation of EC Directive 86/278 (Sludge) and is supported by the Code of Practice for Agricultural Use of Sewage Sludge 1989.

As a note of caution the Soil Code adds that an increase in soil organic matter, such as when compost is added, increases the availability of N and that practices should be adjusted to take account of this to minimise leaching. The Soil Code reiterates the maximum permissible total N additions in organic manures, including compost, as laid out in the water code at 250 kg N ha^{-1} yr^{-1}, or 500 kg N ha^{-1} once in two years in less sensitive areas. In addition it points out that certain potentially toxic elements (PTEs) are hazardous to plants, others to human or animal health, and provides limits for these both in soil and in the material to be added on the basis of whichever is at greater risk; plants, animals or humans. It takes no account of the effects on micro-organisms.

Permitted limits of PTEs in soil are supplied according to pH, reflecting the increased availability of some elements in more acidic conditions. Soil under permanent grass is treated differently as the risk is confined to the root zone and effects on grazers. PTE loading rates are also considered so it is necessary to know concentrations in material that is to be added to land. As in the sludge regulations the PTEs recognised are Zn, Cu, Ni, Cd, Pb, Hg and Cr, with the addition of Mo, Se, As and F. It should be noted that Zn and Cu are also essential trace elements that are only potentially problematic in high concentrations. It is considered unlikely that any other potential contaminants will pose a problem if these are kept within the defined limits. Research has shown that for compost it is usually the case that the nutrient content would limit the amount which can be applied to the land rather than the PTE content. Soil analysis is recommended to keep information on the situation current.

Most organic contaminants are volatilized or rapidly broken down, although PCBs are slower. The Code notes that the breakdown products may be harmful. However, it states that further research is necessary before any meaningful limit levels can be set for these chemicals.

Guidance specifically for compost use is minimal and is only geared towards agriculture. However, as with the Water Code, responsible farmers will tend to comply with the practices laid down in this Code. If composts are to be applied to agricultural land, users must be informed as to the quality of the compost sufficient to enable them to use it in accordance with the Code.

8.5.3 Code of Practice for Agricultural Use of Sewage Sludge (1996)

This is the Code of Practice which supports The Sludge (Use in Agriculture) (Amended) Regulations 1989. Its aim is to ensure compatibility of the content of the Regulations with good agricultural practice. It only covers sewage sludge as used in agriculture, but in view of the potential increase in sewage sludge which will need alternative disposal methods to dumping at sea after 1998, its inclusion in composted materials for agriculture and other uses is likely to increase.

As with the other Codes of Practice already outlined above, it is recommended that N added to soil should be limited on the basis of total content. Reference is made to the EC Nitrate Directive, which limits application to 210 kg N ha^{-1} yr^{-1}, or less in sensitive or vulnerable zones. It is also noted that P levels tend to be high in sewage sludge and it is recommended that crop requirements should be taken into account in calculating the amount of P it is wise to apply.

Methods of application are discussed according to use and risk. Direct injection carries a lower risk of communicating disease and PTEs to grazing animals and volatilisation of such compounds as ammonia, whereas surface spreading has a lower associated risk of nitrate leaching. It is recommended that the risk of pathogens is reduced by leaving land for an interval after application before grazing is recommenced.

As heavy metals persist in the soil, loading needs to be carefully monitored, and limited if necessary. The UK Sludge Regulations at present list limit levels for PTEs in soil, including heavy metals, near the upper end of the range indicated in the EC Directive on sludge. These were defined to protect against phytotoxicity, with consideration to human and animal welfare. No level is included for Cr as it is usually found in the trivalent form which has a relatively low toxicity. Levels are set as total concentrations rather than bioavailable or extractable content as the chemical form of metal in the soil can change over time. As the presence of one can influence the effectiveness of another, each individual PTE level is determined assuming all the others are at maximum in the hope of ensuring a satisfactory margin of safety.

PTE contamination is considered irreversible and it is therefore better to err on the side of caution. If the Code is revised, lower levels may be adopted. These would have to be taken into account if any compost is to include sewage sludge.

8.5.4 A Manual of Good Practice for the Use of Sewage Sludge in Forestry (1992)

The manual was devised to enable users to maximise the fertilising benefits of sewage sludge while minimising adverse environmental problems. Sewage sludge application to non-agricultural land is classed as industrial waste usage but can be exempted under the Control of Pollution Act 1974 Part 1 if used as a fertiliser or beneficial conditioner of the land. The Sludge (Use in Agriculture) (Amended) Regulations 1989 and associated Code of Practice do not apply to forestry but aspects of these are adopted as considered appropriate.

Guidelines are given for the safe use of sludge within the context of forestry. Water and soil sampling details and responsibilities are included. Recommended practices are based on consideration of the safety of the trees and wildlife.

In terms of nutrient addition, application is averaged out over stages in tree growth. Total N limits are given as 1000 kg N ha^{-1} during the pre planting and establishment phase, and 1000 kg N ha^{-1} over the pole stage with a minimum of three years between applications of a maximum of 200 m^3 ha^{-1}. Annual limits of sludge as liquid or cake are given and related to site characteristics such as slope. Levels of PTEs are set according to the Sludge Regulations taking into account the acidic nature of forest soils.

As with the Sludge Regulations and Code of Practice, only sewage sludge is included and no mention is made of other organic soil ameliorants. Practices and limits are applicable only to the forestry industry.

8.6 The 2nd Draft of the EU Biowaste Directive

The issue of compost standards was discussed above. The 2nd Draft of the Biowaste Directive contains three elements which would be of major significance were a Directive to come into force in this form. These relate to:

- Requirements for source separation;
- Standards for processes and outputs (distinguishing between products and wastes); and
- Related to the issue of standards, the eligible use of outputs on land.

In what follows, we clarify the key points in each of these areas, commenting (in passing) on what we understand to be the current state of play as the Commission finalises the Directive (which it is committed to come forward with in 2004).

8.6.1 Separate Collection

As regards separate collection, the Document effectively mandates, other than in specified circumstances, source separation of biowastes. Hence:

> *Member States shall set up, where they are not already in place, separate collection schemes with the aim of collecting biowaste separately from other kinds of waste in order to prevent the contamination of biowaste with other polluting wastes, materials and substances.*
>
> *In particular, the following biowastes – if it can be reasonably expected that their biological treatment will not significantly worsen the quality of the resulting compost or digestate – shall be separately collected, unless they are home composted or community composted:*
>
> *(a) food waste from private households;*
>
> *(b) food waste from restaurants, canteens, schools and public buildings;*
>
> *(c) biowaste from markets;*
>
> *(d) biowaste from shops, small businesses and service undertakings;*
>
> *(e) biowaste from commercial, industrial and institutional sources unless used on site;*
>
> *(f) green and wood wastes from private as well as public parks, gardens and cemeteries.*
>
> *Paper and cardboard waste are biodegradable and quite easily composted. However, when practicable, these wastes should be recycled.*
>
> *The separate collection schemes shall be organised in such a way that any nuisance – caused in particular by odours, insects, rodents, dust and noise – is minimised during collection, transport and treatment.*
>
> *These separate collection schemes shall at least cover:*
>
> *(a) urban agglomerations of more than 100 000 inhabitants within three years;*
>
> *(b) urban agglomerations of more than 2 000 inhabitants within five years.*
>
> *Member States may waive the obligation of separate collection of biowaste:*
>
> – *in inner cities where the logistic of separate collection may make it difficult to achieve a low level of contamination of biowaste with other polluting wastes, materials and substances;*
>
> – *in rural or scarcely populated areas with a density of less than 10 inhabitants per square kilometre in which the setting up of separate collection schemes would not be environmentally justified. In these areas special campaigns to particularly promote home, on-site and community composting shall take place.*

> *In order to avoid an unjustified increase in the quantity of sewage sludge, it should be prohibited to dispose of shredded biowaste to the sewer.*[38]

Our understanding is that the mandating of source-separation may be diluted in any final document. This is, to some extent, conjecture at present. It is, in any case, not entirely consistent with the thrust of the Soil Strategy to reverse the position as outlined above, given the desire of the Soil Strategy to make use of organic wastes, whilst simultaneously respecting the principle of seeking to achieve no net accumulation of potentially toxic elements in soil over time. Arguably, consistency can only be maintained where source separation is encouraged.

8.6.2 Standards

Research elsewhere by Eunomia has reviewed the issue of standards.[39] As a generalisation:

- Process standards are difficult to establish. These tend to be relatively limited in national systems of standards for compost;
- Product standards are more common (and are often used to determine the effectiveness of processes). Those suitable for being placed upon a statutory footing tend to be those which reflect precautionary issues related to (human, animal and plant) health and the environment rather than issues of marketing to specific end-users.

The Document broadly reflects this. Hence, with regard to process standards, the following apply:

> *An indicator organism shall be used in order to determine the effectiveness of the treatment in sanitising biowaste. This test shall be carried out for each treatment plant within 12 month of its starting up phase.*
>
> *The test shall be repeated if the composition of the biowaste significantly changes or if major modifications to the process treatment are made.*
>
> *The indicator organisms shall be Salmonella senftenberg W775 (H_2S negative) [under review].*

Standards for products include the following:

- *Compost/digestate is deemed to be sanitised if it complies with the following:*
  - *Salmonella spp* — *absent in 50 g of compost/digestate [under review]*
  - *Clostridium perfringens* — *absent in 1 g of compost/digestate [under review]*
- *Compost/digestate shall have less than three germinating weed seeds per litre.*

In respect of potentially toxic elements, the Document sought to distinguish between two different classes of compost / digestate (Class I and Class II) and a category of material defined as ‘stabilised biowaste’ (see Table 15).

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[38] European Commission, DG Environment (2001) *Working Document: Biological Treatment of Biowaste*, 2nd Draft, Brussels, 12 February, 2001.

[39] See Dominic Hogg, Josef Barth, Enzo Favoino, Massimo Centemero, Valentina Caimi, Florian Amlinger, Ward Devliegher, Will Brinton and Susan Antler (2002) *Comparison of Compost Standards Within the EU, North America and Australasia*, Final Report to WRAP, 2002.

Table 15: Standards for Compost / Digestate

Parameter	Compost/digestate (*)		Stabilised biowaste (*)
	Class 1	Class 2	
Cd (mg/kg dm)	0.7	1.5	5
Cr (mg/kg dm)	100	150	600
Cu (mg/kg dm)	100	150	600
Hg (mg/kg dm)	0.5	1	5
Ni (mg/kg dm)	50	75	150
Pb (mg/kg dm)	100	150	500
Zn (mg/kg dm)	200	400	1 500
PCBs (mg/kg dm) (**)	-	-	0.4
PAHs (mg/kg dm) (**)	-	-	3
Impurities >2 mm	<0.5%	<0.5%	<3%
Gravel and stones > 5 mm	<5%	<5%	-

(*): Normalised to an organic matter content of 30%.
(**): Threshold values for these organic pollutants to be set in consistence with the Sewage Sludge Directive.

Whenever such standards are set, it is usual to set 'tolerance limits' for the samples tested. Table 16 sets out the Document's view as to the number of samples which may be allowed to fail, and by how far, if the output from a given facility is to remain within a particular Class of material.

Table 16: Tolerance Levels for the Outputs from Biowaste Processing Plants

Series of samples taken in any twelve-month period	Maximum permitted number of samples which fail to conform to any given parameter	Allowed deviation from statutory limit of samples which fail to conform to any given parameter
2	1	20%
4	1	20%
12	3	20%

It should be noted that the above limits cannot be met by simply diluting the presence of certain elements with other materials. The mixing rule in the Document states:

> *The mixing of different materials solely for the purpose of diluting pollutants shall be prohibited.*
>
> *Any mixing of compost or digestate with other suitable materials (such as mineral fertilisers, peat or biowastes suitable for being spread on land without treatment) in order to obtain high-quality plant nutrients and soil improvers shall be regarded as compost or digestate respectively for the purposes of this working document.*

Specific to anaerobic digestion processes, one finds the following:

> *The anaerobic digestion process shall be carried out in such a way that a minimum temperature of 55 °C is maintained over a period of 24 hours without interruption and that the hydraulic dwell time in the reactor is at least 20 days.*
>
> *In case of lower operating temperature or shorter period of exposure:*
>
> – *the biowaste shall be pre-treated at 70 °C for 1 hour, or*

– *the digestate shall be post-treated at 70 °C for 1 hour, or*

– *the digestate shall be composted.*

In addition, it sets emission limit values for the combustion of biogas in Annex VI:

(1) When biogas is used as a fuel in internal combustion engines, the following emission limits shall be complied with (normalised to 5% O_2 in the exhaust gases):

Parameter	Unit	Limit value
Dust	mg/m³	50
NO_x	mg/m³	500
SO_2	mg/m³	500
CO	mg/m³	650
H_2S	mg/m³	5
HCl	mg/m³	30
HF	mg/m³	5

(2) The above-mentioned parameters shall be measured once a month in first three months of operation of the combustion engine and every year thereafter.

(3) To prevent the formation of dioxins, the concentration in biogas of total halogenated hydrocarbons (AOX) shall be lower than 150 mg/m³.

(4) Biogas that cannot be used on-site or upgraded to natural gas quality shall be flared.

When flaring biogas, the outlet temperature of the flue gas shall be at least 900°C and the residence time 0.3 seconds. The maximum concentration of sulphur compounds in biogas shall be 50 ppm or a removal efficiency of at least 98% shall be proven.

(5) In case of upgrade of biogas to natural gas standards, the use of the upgraded biogas shall be subject to the Community provisions pertaining to natural gas transport and use.

(6) Community standards for the parameters listed in this Annex should be developed. Until these standards are approved, Member States may apply national standards and procedures.

Our view of the current status of the Directive is that irrespective of whether the Directive mandates source-separation or not, it seems likely that product and process standards would be included, either in the form as above, or in some amended form. This would imply that the term 'compost' had some specific meaning, differentiating it from 'stabilised waste', and 'waste' more generally. Potentially, this helps to plug a major gap which remains in UK waste legislation – the absence of standards for compost. The absence of these is effectively leading, in parts of the UK, to proposals for plants which purport to generate 'compost', but which, under the standards as they are currently drafted, would be producing stabilised biowaste. The potential for plants to dilute contaminants from mixed waste by mixing with minerals would most likely be ruled out. As such, one might suppose that in future, in order to generate 'compost', a biowaste processing plant would most probably need to use (as its feedstock) source-separated biowastes, rather than a 'biodegradable fraction' separated from residual waste.

8.6.3 Use of Treated Biowastes

The key difference between the Classes of compost relates to the restrictions applied to them in terms of their application to land. These are set out below:

> *Where conditions so demand, Member States may restrict the land use of treated or untreated biowaste and take more stringent measures than those provided for in this section.*
>
> *Whenever justified for ensuring a higher level of environmental protection or for improving the quality and characteristics of the soil, the competent authority shall decide, on a case-by-case basis, on lower or higher maximum allowable quantities than those provided for in this section.*

- *Compost or digestate of class 1 shall be used according to best agronomic practice without any specific restriction. Compost or digestate of class 2 shall be used in a quantity not exceeding 30 tonnes dry matter per hectare on a three-year average.*
- *Member States may authorise the use of stabilised biowaste fulfilling the requirements of Annex III as a component in artificial soils or in those land applications that are not destined to food and fodder crop production [such as final landfill cover with a view to restoring the landscape, landscape restoration in old and disused quarries and mines, anti-noise barriers, road construction, golf courses, ski slopes, football pitches and the likes].*

  For spreading on land or in areas likely to be in direct contact with the general public, stabilised biowaste shall also fulfil the sanitation requirements laid down in Annex II.

  The use of stabilised biowaste shall be allowed on condition of not being repeated on the same areas for at least 10 years and for a total quantity not exceeding 200 tonnes of dry matter per hectare.

  The spreading on land of stabilised biowaste shall take place under control of the competent authority and shall at least be subject – mutatis mutandis – to the provisions of Articles 5 (1) [heavy metal limits in soil], 9 [soil analysis & analytical methods] and 10 [record keeping] of Directive 86/278/EEC. [i.e. the Sewage Sludge Directive].

It is clear from the above that the Biowaste Directive is seeking to protect soils, and to minimise the build up of potentially toxic elements in soil. This theme has been carried forward in the discussions surrounding the development of a Soil Strategy for the EU following on from European Commission's Communication to the Council and the Parliament *'Towards a Thematic Strategy for Soil Protection'*. This states:

> *By the end of 2004 a directive on compost and other biowaste will be prepared with the aim to control potential contamination and to encourage the use of certified compost.*

The pre-amble to the Animal By-products Regulation also states:

> *the Commission has given a commitment that by the end of the year 2004 a Directive on biowaste, including catering waste, will be prepared <u>with the aim of establishing rules on safe use, recovery, recycling and disposal of this waste and of</u> **<u>controlling potential contamination</u>**.*

8.7 Regulations Concerning Organic Agriculture

8.7.1 UK Register of Organic Food Standards (UKROFS): Standards for Organic Food Production

The UK Register of Organic Food Standards (UKROFS) is an independent third party organisation set up at the request of MAFF as a production standard and register of approved organic food producers. It is the certifying body for organic food production which administers the EEC Regulation for Organic Production (2092/91 as amended) in the UK.

Organic farmers using composted materials must adhere to these regulations. Approved substances for use on the land are listed and include source-separated household waste and green waste. Any soil amendment must conform to limits for PTEs as set out in the regulations. In the UK, the Soil Association conforms to and administers an inspection regime in accordance with the UKROFS standards.

8.7.2 The Soil Association Organic Marketing Company Ltd : Standards for Organic Food and Farming

The Soil Association is registered with UKROFS as an Approved Organic Sector Body, and is licensed to certify organic food production and processing under EC Regulation 2092/91. This ‘symbol scheme’ conforms to the content of the UKROFS standard and its symbol inspectors are registered as UKROFS inspectors. The scheme is accredited under the International Federation of Organic Agriculture Movements (IFOAM) Accreditation Programme for Certification of Organic Crop Production, Processing, Livestock and Wild Products. Food which is to be sold as ‘organic’ under the Soil Association symbol must be produced under licence.

The standards reiterate the need for regular input of organic residues for sustainable crop growth and allow the use of materials produced on-farm, but add certain restrictions for materials brought in from elsewhere. Such materials must have been ‘properly composted’. If feedstock containing straw or manures comes from sources which do not employ organic practices, they must have been composted for at least six months or stacked for a minimum of 12 months. Plant waste including VFG must have been composted for at least three months or stacked for six months. Materials containing sewage sludge are specifically prohibited.

Composting is defined as an aerobic fermentation process. Guidelines are given concerning recommended practice regarding the process methodology which should be followed, but these are guidelines only. The temperature of the heap is important from the hygiene aspect. It is suggested that temperatures are maintained at 60 ^{o}C (though no time period is specified) to facilitate the destruction of most weed seeds, pathogens, chemical residues and antibiotics. It is recommended that an aeration regime, such as turning of windrows, should be implemented with a view to achieving these levels. After the initial thermophilic period, the material should be thoroughly mixed then preferably covered for a further period of at least three months to mature. These recommendations are based on a windrow system of composting.

The new classification for ‘composted household refuse’ has been allocated very low maximum limits for PTEs (the limit values for manure are very much higher, even adjusting for nutrient content, especially when one considers that manure is not ‘stabilised’ in the same way as compost). As in other European countries, these have been shown to be too low for most composters to meet even where source-separation is carried out very accurately by householders. In addition, concerns regarding the diffusion of genetically modified products in the food chain have further hindered the prospects for use of compost from biowastes in organic agriculture. Essentially, this is only permitted as long as the producer gives a written guarantee that the material does not contain genetically modified organisms.

Although these standards are applicable only to organic growers, it should be remembered that this is an expanding industry. The benefit of the addition of compost to the land is recognised and even encouraged, which could lead to an increasing demand in this sector of agriculture. Farmers will then need to know nitrogen and PTE content of the material they use in order to make decisions concerning application rates and so on.

In addition, growers will need to be assured that the composting process is adequate. In fact, composting sites are applying for, and being awarded, approval for use of a Soil Association symbol on their product. Sites are inspected to ensure that the composting process is carried out properly and that due care has been taken to minimise environmental impacts, in the treatment and disposal of leachate, for example. Organic growers are therefore assured that the material is suitable for their use within the practices laid down in the standards. The symbol is, however, recognised for its connection with organic production and may have problems gaining acceptance outside this specialist area.

8.7.3 HDRA Certification Scheme for Organic Landscaping and Amenity Horticulture

Recently, HDRA (the Henry Doubleday Research Association) has been working with the Soil Association to develop a scheme for the organic certification of those involved in landscaping and amenity horticulture. The limit values for PTEs are essentially the same as under the UKROFS system, but the HDRA scheme, since it does not apply to agriculture, is not constrained by the same legislation as the UKROFS scheme (which mirrors EU legislation on organic farming).

Our understanding is that the scheme (which is in its infancy) will look rather similar to the Soil Association scheme but that the applicable limit values may change in due course. However, the processes which it is recommended that producers of compost follow are rather similar. There is some overlap in the area of horticulture. It is intended that professional users will adhere to the Soil Association certification, but that amateur horticulturists may make use of products certified under the HDRA scheme (and presumably, this becomes more significant the more the HDRA standard differs from that of the Soil Association).

Some producers of compost already make use of an 'HDRA symbol'. We understand that this symbol will be phased out as the new standards enter the marketplace.

8.8 Summary

It is no secret that the regulation of the management of biowastes in the UK as a whole has been, and to some extent remains, wholly unsatisfactory. Moves are afoot to change this. We have discussed above how the absence of product standards has been apt to lead to confusion regarding the quality of outputs. Even quite recently, definitions for 'compost', which effectively guide local authorities as to how they meet targets set for them, have been so vague as to lead to a plethora of applications for so-called composting facilities, the feedstock for which is mixed waste.

The use of mixed waste, as opposed to source-separated material, makes it unlikely that operators can meet either the standard proposed by WRAP and the Composting Association (the PAS 100), or the standards in the 2nd Draft of the Biowaste Directive. This applies equally to composting and digestion facilities (though the possibilities for getting close to quality standards are greater for digestion plants (which incorporate wet separation) than they are for composting plants).

As such, the existing lack of clear definitions, the absence of any statutory standards and the vagueness of the Waste Management Licensing Regulations makes it likely that the lack of any serious and consistent form of regulation will lead to poor investments in both collection and treatment infrastructure. On the more positive side, it seems likely that European legislation, as well as the initiatives of WRAP, will increasingly align the UK with what is expected to emerge under a Biowaste Directive, itself influenced by the negotiations around a Soil Strategy.

As far as digestion is concerned, the picture is looking more positive than it was, but arguably, this is not saying much. The main change of significance is the possible inclusion of digestion under Best Value targets, from which it has hitherto been excluded.

We would strongly advise Northern Ireland to consider the following approach for setting targets for local authorities (or regions, or the nation) where material recovery are concerned:

1. Ensure that there is no chance of confusing the terms 'composting' and 'anaerobic digestion'. As such, the biowaste aspect of materials recovery ought to refer to 'biological treatments', or 'bioprocessing';

2. The aim should be to link targets for materials recovery to standards which maximise the likely benefits from the use of the output materials, and minimise the potential for build up of heavy metals in soil. This suggests linking the materials recovery targets to standards set in the PAS 100, or in the Biowaste Directive (2^{nd} Draft).

It might be asked, where does this leave the slurries from AD which are sometimes applied to land? Our view is that good practice would require separation of solid and liquid fractions before application to land. The 2^{nd} Draft Biowaste Directive hints at this, but it is far from unequivocal.

Just before Christmas of 2003, the European Commission issued a Draft Discussion Document in which the issues raised by the proposed Biowaste Directive, and expected revisions to the Sludge Directive, were discussed.[40] Some important issues were flagged in respect of digestion in Annex II of the document. This included the flagging up of the following consideration:

- *The use of digestion residues from anaerobic digestion should be subject to Directive 75/442/EEC and to a monitoring system equivalent to the one in force for sewage sludge in case of landspreading,* ***unless they are composted****.*

This would mean that the material would not be deemed to have been 'recovered' unless the solid fraction of digestion residuals was composted. As such, it seems sensible to be seeking this from new digestion plants, this being good practice anyway.

At the time of finalising this document, there was some discussion that the Biowaste Directive had been 'dropped' by the Commission. This does not appear to be the case, and indeed, the Director-General of the Environment Directorate has been urged by a group of representative bodies including Assure, FEAD, ISWA, EEB, ECN and RREUSE to respect the previous commitment to come forward with a Directive on Biowaste in 2004. It states:

> *'we call for the development of clear regulatory guidelines for biowaste recovery under a framework soil directive without any undue delay. It should be based on the Soil Advisory Forum's Technical Working Group report on organic matter, and aim to:*
>
> - *Move materials up the waste hierarchy*
> - *Promote 'front of pipe' solutions to minimise contamination*

[40] *European Commission Draft Discussion Document for the Ad-hoc Meeting on Biowastes and Sludges: 15-16 January 2004*, Brussels, DG Environment, 18 December 2003.

> - *Establish standards, which can be applied to the output for composting or other biological treatment options. Quality standards would serve to classify these materials as "products" and ensure their further use in appropriate applications for improved environmental protection and improvement of soils*
>
> *Our vision is to see the sustainable management and application to land of exogenous organic matter across the European Union and we urge you to reinstate the Commission's previous commitment to develop regulatory guidelines for biowaste recovery during 2004.'*

Hence, the Directive may yet emerge, either within a Soil Strategy, or as a stand alone Document.

9.0 THE ANIMAL BY-PRODUCTS REGULATIONS

It is ironic that at the time new targets for the recycling and composting of waste were being considered, legislation was being drafted which made composting far more difficult. Until recently (July of this year), the Animal By-products Order, as amended (1999), effectively made it an offence to allow livestock (which includes birds) access to catering waste containing meat or products of animal origin, or catering waste which originates from premises on which meat or products of animal origin are handled. The aim was to prevent the introduction and spread of serious animal diseases such as foot-and-mouth disease that can be present in meat.

Although this Order did not prevent the composting or biogas treatment of catering waste containing meat or products of animal origin, Defra's interpretation of it was that it effectively prevented the use of such material on land (whether treated or not), effectively banning composting and biogas digestion as treatment and recovery methods for such catering waste. The consequence of this was that waste policy-makers, local authorities and waste companies struggled to come to terms with the consequences of the Order for their waste strategies.

Following on from the Order, and reflecting concerns related to the potential for the spread of livestock pathogens, the EU developed a new Animal By-Products Regulation (EC 1774/2002).

9.1 The EU Regulation

The Animal By-Products Regulation (EC 1774/2002) establishes different categories of material derived from animals, related to their risks. Three categories are established. In Category 3, the 'lowest risk' category, Article 6 (1) states that:

(l) catering waste other than as referred to in Article 4(1)(e).

is included. Catering waste is defined as *'all waste food originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens'.* The class of catering waste referred to under Article 4(1)(e) is:

(e) catering waste from means of transport operating internationally.

Hence, 'all waste food originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens' which is not *'from means of transport operating internationally'*, falls under Category 3.

Article 6 continues:

Category 3 material shall be collected, transported and identified without undue delay in accordance with Article 7 and, except as otherwise provided in Articles 23 and 24, shall be:

(a) directly disposed of as waste by incineration in an incineration plant approved in accordance with Article 12;

(b) processed in a processing plant approved in accordance with Article 13 using any of processing methods 1 to 5, in which case the resulting material shall be permanently marked, where technically possible with smell, in accordance with Annex VI, Chapter I, and disposed of as waste either by incineration or by co-incineration in an incineration or co-incineration plant approved in accordance with Article 12 or in a landfill approved under Directive 1999/31/EC;

(c) processed in a processing plant approved in accordance with Article 17;

(d) transformed in a technical plant approved in accordance with Article 18;

(e) used as raw material in a petfood plant approved in accordance with Article 18;

(f) transformed in a biogas plant or in a composting plant approved in accordance with Article 15;

(g) in the case of catering waste referred to in paragraph 1(l), transformed in a biogas plant or composted in accordance with rules laid down under the procedure referred to in Article 33(2) or, pending the adoption of such rules, in accordance with national law

This is important. It implies that the Category 3 catering wastes (those defined under paragraph 1(l)) are not to be considered in the same way as the other Category 3 materials, which are to be subject to the requirements of Article 15 (see (g) above). This means that for all "catering waste", which encompasses 'all waste food originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens', then as long as the material is not *'from means of transport operating internationally'*, the appropriate legislation is that which currently exists in Member States, pending rules laid down under the procedure referred to in Article 33 (2).

For all other Category 3 wastes which are to be composted or digested, the relevant article is Article 15. Article 15 refers, in turn, to a number of Annexes to the Regulation which make provision for various measures where Category 3 wastes other than catering wastes are used in biogas and composting facilities.

9.2 The Animal By-products Regulation –UK Implementation

The DEFRA *Public Consultation On The Proposed Use Of Catering Waste Containing Meat In Composting and Biogas Treatment* stated that:

> *'The new EU Animal By-Products Regulation (EC 1774/2002, expected to come into force at the end of April 2003) will permit the use of composting and biogas treatments for catering waste and low-risk animal by-products. Animal by-products must be treated to at least the EU standard, which is 70°C for 1 hour. However, for plants which process only catering waste (not animal by-products), the Regulation allows Member States to specify their own standards at national level, provided that these standards guarantee an equivalent level of pathogen removal.'*

It will be noted that this is not actually correct. The Member State policies are under no obligation to achieve equivalence with what appears under Article 6 (because this does not apply to those catering wastes which are not *'from means of transport operating internationally'*).

The Defra statement appears to reflect requirements laid down in Annex VI of the Regulations:

12. Category 3 material used as raw material in a biogas plant equipped with a pasteurisation/hygienisation unit must be submitted to the following minimum requirements:

(a) maximum particle size before entering the unit: 12 mm;

(b) minimum temperature in all material in the unit: 70°C; and

(c) minimum time in the unit without interruption: 60 minutes.

13. Category 3 material used as raw material in a composting plant must be submitted to the following minimum requirements:

(a) maximum particle size before entering the composting reactor: 12 mm;

(b) minimum temperature in all material in the reactor: 70°C; and

(c) minimum time in the reactor at 70°C (all material): 60 minutes.

14 However, pending the adoption of rules in accordance with Article 6(2)(g), the competent authority may, when catering waste is the only animal by-product used as raw material in a biogas or composting plant, authorise the use of processing standards other than those laid down in paragraphs 12 and 13 provided that they guarantee an equivalent effect regarding the reduction of pathogens.

The emboldened paragraph is what seems to be referred to in the DEFRA Consultation. Yet this Annex does not apply where catering wastes are being composted / digested, but it is to be applied where other Category 3 wastes are being composted / digested (i.e. those under Article 6(2)(f) which are subject to Article 15, which in turn refers to Annex 6 and other Annexes).

The emboldened paragraph above is somewhat confusing. Article 6(2)(g) is irrelevant in this Annex since the materials affected by Article 6(2)(g) are not those to which Annex VI applies. It could be that this was intended to apply only to those catering wastes which do not fall under Category 3, i.e. those *'from means of transport operating internationally'*. Even so, this is still rather confusing since Article 6(2)(g) is irrelevant to these wastes by virtue of Article 6 (g).

This is important since it has had a bearing on the introduction, by DEFRA, of new legislation designed to supplant the EU Regulation, and allow the composting and digestion of catering waste under specific conditions. In doing this, they have taken the view that catering wastes effectively fall under Article 6(2)(f) (as opposed to Article 6(2)(g)). Both allow for national regulations to be applied, but for Article 6(2)(f) wastes, the default situation is provided by standards in the EU Regulation under Annex VI. Under Article 6(2)(g), the situation is that national legislation can apply until rules are laid down, probably (it would seem) in a Biowaste Directive.

The Commission did seek to make this explicit to Member States through Guidance provided by DG SANCO.[41] Point 21 of this states quite categorically:

> *"the commission accepted to include catering waste in the scope of the regulation on condition that such inclusion would not hinder any development of new rules on environmental protection, avoiding any negative impact on current national policies in particular as regards biowaste.* ***Therefore, the Regulation does not lay down rules for the treatment of catering waste that is subject to composting or biogas treatment. Instead it establishes in Article 6(2)g that pending the adoption*** *.....etc."*

Even more sharply sentenced is the following part of point 21:

> *"The processing standards in Chapter II(C), Annex VI of the Regulation relate to the approval requirements pertaining to biogas and composting plants set out in Article 15.* ***These processing standards do not affect the provision in Article 6(2)(g), which specifically exempts catering waste*** *(other than from means of transport operating internationally), when it is the only ABP used as raw material for a biogas or composting plant (see the answer to question 20, above).* ***The Commission will consider modifying the wording in paragraph 14 of Chapter II(c) of Annex VI in order to avoid possible confusion****".*

The distinction between catering wastes, and all other wastes under Category 3, is therefore unequivocal.

In implementing the Animal By-products Regulation, DEFRA has effectively gone far beyond what the EU Regulation requires, certainly as regards kitchen waste. The basis for its doing so was a Risk

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[41] "from the farm to the fork") at **http://europa.eu.int/comm/food/fs/bse/bse48_en.pdf**

Assessment which includes many highly questionable assumptions concerning the effect of the composting process on the presence of pathogens, and the likely presence of infected meat in the UK.[42]

Hence, in DEFRA's original consultation on amending the ABPO, one found the following statements:

> *The EU Regulation requires that the composting of catering waste containing meat must take place in a 'closed composting reactor'.*

This is simply wrong. This requirement, part of Annex VI, applies to non-catering Category 3 material, not to catering wastes.

Elsewhere, the following statement appeared:

> *The new EU Animal By-Products Regulation (EC 1774/2002, expected to come into force in spring 2003) will permit the treatment in composting and biogas plants of catering waste containing meat and low-risk animal by-products. The treatment standard in the Regulation is 70°C for 1 hour in a closed system. However, for plants processing only catering waste (not animal by-products), the Regulation allows national standards to be set, provided they guarantee an equivalent effect in pathogen reduction.*

This is also incorrect. There is no 'EU Standard' (yet) for catering wastes in the Regulation, and the Guidance makes this clear. The standard referred to is that set out in Annex VI, but <u>this is the standard to be applied to those Category 3 wastes which are not catering wastes</u>. In any case, it seems somewhat unlikely that a Regulation for compost plants which treat kitchen wastes would specify such a small maximum particle size.

Amongst the presentation of options regarding the Amendment, in the Consultation document, one found:

> ***Option 3 Adopt national rules for treatment standards***
>
> *14. This would also meet our obligation to implement EU legislation. <u>The EU rules allow Member States to adopt national standards for the composting and biogas treatment of catering waste, provided that these standards guarantee an equivalent level of pathogen removal to the EU standard.</u>*

The requirement to achieve anything by way of an equivalent level of pathogen removal is a red herring for the same reason as that given above. There is no standard, and hence, no 'equivalence' to be guaranteed. Again, as regards options for change, the 'do nothing option' is discussed as Option 1:

> *16. Option 1 - no perceived benefit as the rules would not change. Upon introduction of the EU Animal By-Products Regulation, the UK would be in breach of its obligation to implement EU legislation and would be open to legal challenge.*

Ironically, this was not true either, since at least for those catering wastes not from international transport, the existing legislation is effectively what is suggested. This does not mean the UK should have continued to ban the composting of catering wastes. It does mean that in rescinding the ban, DEFRA did not have to adhere to any existing EU standard because none such existed, though it might be argued it was sensible to adopt the standards already proposed (after much discussion) in, for

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[42] P. Gale (2002) *Risk Assessment: Use of Composting and Biogas Treatment To Dispose of Catering Waste Containing Meat*. Final Report to the Department for Environment, Food and Rural Affairs. WRc plc; May 2002. For a critical review, see D. Hogg (2003) *Risk Assessment and the ABPR: A Critical Review of the UK Approach*, presentation to the ECN/ORBIT Conference, Maastricht, October 2003.

example, the Second Draft Biowaste Directive. As mentioned above, such a Directive is due to emerge '*by the end of 2004*.'

What one can say is that the rationale for the development of the UK Statutory Instrument, to the extent that this is supposedly provided by the EU Regulation, is actually 'not there'. DEFRA has effectively 'over-interpreted' the Animal By-products Regulation. Whilst DEFRA is entitled to do this (since it is allowed to apply national legislation), the possibility remains that subsequent moves at the EU level may actually force DEFRA to alter its newly implemented legislation. This could take the form of Technical Criteria developed under the envelope of the EU Regulation (and such standards are being considered by DG SANCO), or a new Biowaste Directive, or a combined Directive applied to both Biowaste and Sludge. In the mean time, the supposed justification for Defra taking the position it has is to be found in the Risk Assessment carried out on 2002, which does not bear close scrutiny.

9.3 Key Details of the Statutory Instrument

In what follows, we elaborate the details of the Statutory Instrument (the Regulations),[43] drawing upon the Defra Guidance[44] (the Guidance) to clarify the intent as far as possible. We have concentrated on key issues in terms of:

1. Process Management
2. Record Keeping; and
3. Use of Outputs

By way of introduction, the UK Regulations follow the Community Regulation in dividing animal by-products into three distinct 'risk categories', with Category 1 posing the greatest risk, and Category 3, the least. Catering wastes are classified as Category 3 material (the other classes were noted above). The significance of these different categories is that the Community Regulation stipulates which treatments are allowable for each of the three categories of material. For category 3 material, in the Community Regulation, acceptable treatments are:

(a) directly disposed of as waste by incineration in an incineration plant approved in accordance with Article 12;

(b) processed in a processing plant approved in accordance with Article 13 using any of processing methods 1 to 5, in which case the resulting material shall be permanently marked, where technically possible with smell, in accordance with Annex VI, Chapter I, and disposed of as waste either by incineration or by co-incineration in an incineration or co-incineration plant approved in accordance with Article 12 or in a landfill approved under Directive 1999/31/EC;

(c) processed in a processing plant approved in accordance with Article 17;

(d) transformed in a technical plant approved in accordance with Article 18;

(e) used as raw material in a petfood plant approved in accordance with Article 18;

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[43] *The Animal By Products Regulations 2003*, Statutory Instruments 2003, no.1482; .

[44] *Animal By-products Regulation (No. (EC) 1774/2002) and Animal By-products Regulations 2003 (SI No. 1482/2003): Draft Guidance On The Treatment In Approved Composting Or Biogas Plants Of Animal By-Products And Catering Waste*, Defra July 2003

(f) transformed in a biogas plant or in a composting plant approved in accordance with Article 15;

(g) in the case of catering waste referred to in paragraph 1(l), transformed in a biogas plant or composted in accordance with rules laid down under the procedure referred to in Article 33(2) or, pending the adoption of such rules, in accordance with national law;

(h) in the case of material of fish origin, ensiled or composted in accordance with rules laid down under the procedure referred to in Article 33(2); or

(i) disposed of by other means, or used in other ways, in accordance with rules laid down under the procedure referred to in Article 33(2), after consultation of the appropriate scientific committee. These means or ways may either supplement or replace those provided for in subparagraphs (a) to (h).

Perhaps the key point here is the absence of 'landfill'. In other words, it appears to be the intention to ensure that no such wastes are landfilled in future. Indeed, composting and anaerobic digestion are the only accepted treatments for Category 3 materials.

UK implementation of the Community Regulation allows for catering wastes to be treated slightly differently from other Category 3 wastes. 'Catering waste' is defined under the EU Regulation as *'all waste food including used cooking oil originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens.'* In the case of catering waste, the process requirements specified for catering waste in the UK regulation may apply. However, if a process also composts, or digests, other Category 3 material, or if the operator prefers to comply with alternatives to the process requirements for catering wastes, the regulations laid down in the EU Regulation (Annex VI) apply. This is important for digestion plants which seek to co-digest catering wastes alongside other Category 3 wastes. We discuss this in the following section.

9.3.1 Process Requirements for Catering Wastes

The UK Regulations effectively require treatment of catering wastes to a standard equivalent to the Requirements of Annex VI of the Community (i.e. EU) Regulation, even though this was not the intent of the regulation.

> ***Biogas and composting plants***
> ***15.*** *- (1) The provisions of Part I of Schedule 1 to these Regulations shall apply in a biogas and composting plant used for treating any animal by-products (including catering waste) in addition to the requirements of paragraphs 1 to 11 of Annex VI, Chapter II to the Community Regulation.*
> *(2) In accordance with Article 6(2)(g) and Annex VI, Chapter II, paragraph 14 to the Community Regulation -*
>
> > *(a) catering waste shall be treated in a biogas or composting plant either in accordance with Annex VI, Chapter II, paragraphs 12 or 13 to the Community Regulation or in accordance with Part II of Schedule 1 to these Regulations; and*
> > *(b) any other animal by-product treated in a biogas or composting plant shall be treated in accordance with Annex VI, Chapter II, paragraphs 12 or 13 to the Community Regulation.*
>
> *(3) Any person who fails to comply with any provision of this regulation shall be guilty of an offence.*

The process requirements of Schedule 1 are set out in Box 2.

Box 2: Schedule 1 of the ABPR

Regulation 15

ADDITIONAL REQUIREMENTS FOR BIOGAS AND COMPOSTING PLANTS

PART 1 - PREMISES
1. - (1) There shall be -
(a) a reception area in which untreated animal by-products (including catering waste) are received;
(b) an area in which vehicles and containers are cleansed and disinfected with adequate facilities for doing this; and
(c) a clean area in which treated compost or digestion residues are stored.
(2) The clean area shall be adequately separated from the reception area and the area in which vehicles and containers are cleansed and disinfected so as to prevent contamination of the treated material. Floors shall be laid so that liquid cannot seep into the clean area from the other areas.
(3) The reception area shall be easy to clean and disinfect and shall have an enclosed and lockable place or container to receive and store the untreated animal by-products.
2. The animal by-products shall be unloaded in the reception area and either -
(a) treated immediately; or
(b) stored in the reception area and treated without undue delay.
3. The plant shall be operated in such a way that -
(a) treated material is not contaminated by untreated or partially treated material or liquids arising from it; and
(b) partially treated material is not contaminated with material which has not been treated to the same extent or liquids arising from it.
4. The operator shall identify, control and monitor suitable critical points in the operation of the plant to demonstrate that -
(a) these Regulations and the Community Regulation are complied with;
(b) treated material is not contaminated by untreated or partially treated material or liquids arising from it; and
(c) partially treated material is not contaminated with material which has not been treated to the same extent or liquids arising from it.
5. Containers, receptacles and vehicles used for transporting untreated animal by-products shall be cleaned in the dedicated area before they leave the premises and before any treated material is loaded. In the case of vehicles transporting only untreated catering waste and not subsequently transporting treated material, only the wheels of the vehicle need be cleaned.

PART II - TREATMENT SYSTEMS AND PARAMETERS FOR CATERING WASTE
1. Unless an approval specifically permits a different system, catering waste shall be treated by one of the systems specified in the table below. The system shall ensure that the material is treated to the following parameters:
Composting

System	Composting in a closed reactor	Composting in a closed reactor	Composting in housed windrows
Maximum particle size	40cm	6cm	40cm
Minimum temperature	60°C	70°C	60°C
Minimum time spent at the minimum temperature	2 days	1 hour	8 days (during which the windrow shall be turned at least 3 times at no less than 2 days intervals)

The time temperature requirements shall be achieved as part of the composting process.
Biogas

System	Biogas in a closed reactor	Biogas in a closed reactor
Maximum particle size	5cm	6cm
Minimum temperature	57°C	70°C
Minimum time spent at the minimum temperature	5 hours	1 hour

2. The approval shall normally specify one of the methods in the table, but the Secretary of State may approve a different system if she is satisfied that it achieves the same reduction in pathogens as those methods (including any additional conditions imposed on those methods) in which case the approval shall fully describe the whole system.
Composting plants
3. If the approval for a composting plant specifies one of the methods in the table, it shall specify which one and, in addition, shall have as a condition either that -

a. measures shall be taken at source to ensure that meat was not included in the catering waste and that following treatment the material is stored for at least 18 days; or
b. following the first treatment, the material shall be treated again using one of the methods in the table and specified in the approval (not necessarily the same method as was used for the first treatment) except that, if the treatment is in a windrow, the second treatment need not be in a housed windrow.

Biogas plants
4. The approval for a biogas plant shall specify one of the methods in the table and in addition require that either -

a. measures were taken at source to ensure that meat was not included in the catering waste; or
b. following treatment the material is stored for an average of 18 days after treatment (storage need not be in an enclosed system).

It should be noted that in the Guidance, the maximum particle size dimension refers to the maximum dimension in any one plane. In other words, particles can be larger than this in any given dimension provided that the size in any plane is not more than the maximum particle size stated.

It is clear from Box 2 that the UK Regulation deals with processes which treat meat-including wastes differently to those treating meat-excluded wastes. The Guidance defines meat-excluded wastes in the following way:

> *'Meat-excluded' catering waste means that measures were taken at source to ensure that meat was not included in the catering waste. In other words, this means that the meat and non-meat fraction of the catering waste must be separately collected, and never mixed. Meat-excluded catering waste does not mean waste where meat and nonmeat have been collected together and steps subsequently taken to remove the meat fraction from the mix. Rather it means that the meat fraction was never mixed with the non-meat waste stream. It is recognised that it will not be possible to ensure that no meat is ever present and a small amount of meat in a meat-excluded catering waste stream will not necessarily mean that the waste must be treated as non meat-excluded. This risk has already been factored into the risk assessment.*
>
> *Measures taken to ensure separation must be properly recorded and audited. It is suggested that the measures could include clear and regularly reminded instructions to householders backed up with posters/leaflets and clearly labelled warnings on bins, audit at collection, at deposit into collection vehicle and at reception at the treatment facility. Bins may be rejected at point of collection where meat is obviously present, and the householder should be informed why their bin has been rejected. Regular inspection should take place at the treatment facility reception area, to ensure separation is acceptable. Operators should use this to monitor effectiveness of separation, and to trigger the issuing of additional information leaflets if unacceptably high contamination by meat is observed. However, we would expect the measures to be designed to ensure that the separation is as complete as possible.*
>
> *Because the risk to animal and public health comes primarily from meat, the requirement for separate collection applies only to meat and meat products, and does not apply to other products of animal origin i.e. eggshells, cheese and other non-meat products of animal origin can be placed in the non-meat fraction.*

The Guidance also makes clear that garden waste is not affected by the Regulations.

For digestion plants, as far as catering waste is concerned, the Guidance summarises Box 2 as follows:

> *Biogas plants must either*
>
> > *(a) treat only meat-excluded catering waste; or*
> >
> > *(b) following treatment, store the material for a minimum of 18 days. Storage may include anaerobic digestion.*
>
> *For example, a biogas plant could pasteurise catering waste by treating it to 70°C for 1 hour (or 57°C for 5 hours), followed by an 18 day anaerobic digestion stage. Alternatively, a biogas plant could treat only meat-excluded catering waste to the time/temperature standard alone. Both of these would comply with the two barrier requirement for biogas plants.*

For most digestion plants, this poses relatively few problems:

1. The particle size requirement is likely to be met anyway;

2. In many systems, the pre-treatment includes a pasteurization phase, and this can make use of energy from the biogas generated by the process. The 57°C requirement is somewhat tantalising since plants operating in the thermophilic range might operate close to that temperature (55°C or so) and may reach it at the end of the process, but they might not operate quite at this temperature;

3. The storage time requirement is not a major problem since the 18-day period can include the digestion period itself once pasteurization conditions have been met. Typical hydraulic retention times for biowaste digesters are of the order 14-20 days, and good practice involves a post treatment composting stage (usually at the very least one week, but typically two or more weeks).

The UK Regulation certainly seems to require fewer adaptations to AD processes than it does to aerobic composting processes. This is not only due to the requirements imposed for treatment. The part of Box 2 referring to premises requires separation of clean and dirty areas, and requires operators to minimize the possibility of cross contamination of 'clean' (treated) materials by 'untreated materials' (this is the issue of 'by-pass'). Digestion plants, because they tend, by their nature, to be based upon flows of material, are more suited to compliance with these requirements without changes in process design.

An important issue for digestion plants is whether or not they envisage treating other Category 3 Animal By-products in their treatment. If this is the case, they would be required to meet the standard laid down in Annex VI of the EU Animal By-products Regulation, as set out in Annex VI, para.12:

> *12. Category 3 material used as raw material in a biogas plant equipped with a pasteurisation/hygienisation unit must be submitted to the following minimum requirements:*
>
> *(a) maximum particle size before entering the unit: 12 mm;*
>
> *(b) minimum temperature in all material in the unit: 70°C; and*
>
> *(c) minimum time in the unit without interruption: 60 minutes.*

The application of slightly different rules for municipal waste therefore becomes irrelevant in the case of co-digestion with other Category 3 materials, although it would seem that the greater particle size reduction to 12mm (as compared with 60mm for household kitchen waste) might have to be accomplished only for that element of the waste which is Category 3 material. In practice, some operators may simply choose to opt to comply with the EU standard as opposed to that laid down in the UK ABPR (if only because the additional size reduction effectively opens up a wider market for materials to be treated at the plant).

A list of Category 3 wastes is given in Box 3 below.

9.3.2 Record Keeping

The UK Regulation imposes quite strict record keeping requirements. These include:

> ***Delivery records to be kept by operators of biogas and composting plants***
>
> ***36.*** *The operator of any biogas or composting plant receiving catering waste shall record -*
>
> *(a) the date on which the catering waste was delivered to the premises;*
> *(b) the quantity and description of the catering waste, including a statement of whether measures were taken at source to ensure that meat was not included in the waste; and*
> *(c) the name of the haulier;*

and failure to do so shall be an offence.

Treatment records for biogas and composting plants

37. *The operator of a biogas or composting plant treating catering waste or other animal by-products shall record -*

> *(a) the dates on which the material is treated;*
> *(b) a description of the material treated;*
> *(c) the quantity of material treated;*
> *(d) the result of all checks carried out at the critical points identified under paragraph 3 of Part I of Schedule 1; and*
> *(e) sufficient information to show that the material has been treated to the required parameters;*

and failure to do so shall be an offence.

These, however, can generally be considered to be consistent with good practice in terms of quality assurance.

Box 3: Category 3 Materials, as Defined by Article 6, EU Regulation

1. Category 3 material shall comprise animal by-products of the following description, or any material containing such by-products:

(a) parts of slaughtered animals, which are fit for human consumption in accordance with Community legislation, but are not intended for human consumption for commercial reasons;

(b) parts of slaughtered animals, which are rejected as unfit for human consumption but are not affected by any signs of diseases communicable to humans or animals and derive from carcases that are fit for human consumption in accordance with Community legislation;

(c) hides and skins, hooves and horns, pig bristles and feathers originating from animals that are slaughtered in a slaughterhouse, after undergoing ante-mortem inspection, and were fit, as a result of such inspection, for slaughter for human consumption in accordance with Community legislation;

(d) blood obtained from animals other than ruminants that are slaughtered in a slaughterhouse, after undergoing ante-mortem inspection, and were fit, as a result of such inspection, for slaughter for human consumption in accordance with Community legislation;

(e) animal by-products derived from the production of products intended for human consumption, including degreased bones and greaves;

(f) former foodstuffs of animal origin, or former foodstuffs containing products of animal origin, other than catering waste, which are no longer intended for human consumption for commercial reasons or due to problems of manufacturing or packaging defects or other defects which do not present any risk to humans or animals;

(g) raw milk originating from animals that do not show clinical signs of any disease communicable through that product to humans or animals;

(h) fish or other sea animals, except sea mammals, caught in the open sea for the purposes of fishmeal production;

(i) fresh by-products from fish from plants manufacturing fish products for human consumption;

(j) shells, hatchery by-products and cracked egg by-products originating from animals which did not show clinical signs of any disease communicable through that product to humans or animals;

(k) blood, hides and skins, hooves, feathers, wool, horns, hair and fur originating from animals that did not show clinical signs of any disease communicable through that product to humans or animals; and

(l) catering waste other than as referred to in Article 4(1)(e).

9.3.3 Restrictions on Use

In respect of the application of compost to land, the key restrictions are in respect of application of material to land which may be grazed by animals. The Regulations state:

> ***10.*** *Any person who fails to comply with Article 22(1) of the Community Regulation shall be guilty of an offence.*

The Community regulation refers, in Article 22(1), to prohibitions, including '*the application to pasture land of organic fertilisers and soil improvers, other than manure*'. Hence, in order to allow the application of compost to pasture land, a clear definition of the prohibition, and hence of pasture land, was required. The UK Regulations define this as follows:

> ***Pasture land***
> ***11.*** *- (1) For the purposes of Article 22(1)(c) of the Community Regulation, pasture land is land that is intended to be used for grazing or cropping for feeding-stuffs following the application or deposit of organic fertilisers and soil improvers within the following periods -*
>
> *(a) two months in the case of pigs; and*
> *(b) three weeks in the case of other farmed animals.*
>
> *(2) Any person who -*
>
> *(a) uses pasture land for grazing within the period specified in paragraph (1); or*
> *(b) feeds to pigs or other farmed animals within that period anything cropped from pasture land during that period;*
>
> *shall be guilty of an offence.*

These measures mean that effectively, there are specific restrictions on the application of compost to land to protect grazing animals from the possibility of infection. This is because it was argued, in the risk assessment, that grazing would imply the consumption of some untreated material. The storage phase was intended to reduce the presence of infective organisms.

More generally, clear labelling is required, and users of compost and digestion have to keep records of the use of any compost or digestion residues on land:

> ***Placing on the market of compost or digestion residues for use on agricultural land***
> ***24.*** *Any person who places on the market compost or digestion residues for use on agricultural land shall ensure that it is labelled or accompanied by documentation in such a way that the recipient has his attention drawn to the requirements of regulation 11 above (provisions relating to pasture land) and any person who fails to do so shall be guilty of an offence. […]*
>
> ***Records to be kept for consignments of compost or digestion residue***
> ***39.*** *- (1) Subject to paragraph (2), the occupier of premises on which ruminant animals, pigs or poultry are kept shall record -*
>
> *(a) the date on which compost or digestion residue is brought on to those premises;*
> *(b) the quantity and description of the compost or digestion residue;*
> *(c) the land to which the compost or digestion residue is applied;*
> *(d) the date of such application; and*
> *(e) the date on which the land is first cropped or the date on which ruminant animals, pigs or poultry were allowed access to the land, whichever is the sooner;*
>
> *and failure to do so shall be an offence.*

(2) The requirement in paragraph (1) to make records shall not apply in the case of any supply of compost or digestion residue for use at any premises used only as a dwelling.

These may affect, to some degree, the potential market outlets for digestate and / or compost derived from digestate. However, markets related to pasture land, as defined under the UK ABPR, are certainly not the only markets for digestate. A range of other outlets exist from landscaping to horticulture.

9.4 Conclusions

Setting aside the merits or otherwise of the legislation itself, our view of the UK ABPR is that the legislation probably affects aerobic composting rather more than it does anaerobic digestion. Anaerobic digestion plants seem likely to have to make rather minor modifications to their processes, and ones which the nature of the processes are relatively well equipped to deal with. Since many biogas plants produce heat energy on site anyway, the requirements for pasteurization, where such processes were not already carried out as a matter of course, merely have the effect of increasing capital costs (marginally) whilst reducing net heat delivery to other potential users where the plant operates with CHP generators.

The consequence of this is that the cost differentials which have traditionally led to most biowastes being treated through aerobic composting (as opposed to anaerobic digestion) are almost certainly narrowing, at least where the material under discussion includes catering waste. For garden wastes, aerobic composting in open-air windrows remains the cheapest option.

The one-way flow nature of AD systems also lends itself more to the requirement under the UK ABPR to keep clean and dirty areas separate. For some aerobic facilities, the nature of the plant is such that some re-configuration may be necessary. This may have the effect of increasing land-take and the costs of equipment.

Hence, as long as the application of the UK ABPR is sensible, there seems to be little reason why most biogas plants would find compliance problematic. Indeed, many will already be achieving levels of pathogen reduction far in excess of that which the Defra Risk Assessment suggested could be achieved, and which formed the basis for the UK ABPR. The implications are that residues from digestion processes ought to be able to find application in one of a range of different markets.

10.0 ECONOMIC INCENTIVES FOR RENEWABLE ENERGY

10.1 Introduction

Northern Ireland has three major electricity generating stations, each operated by a different company. Supply is dominated by NIE, which manages a network of some 35,000 miles of overhead lines and underground cable (inclusive of LV services), together with the North/South interconnectors. According to DETI, Northern Ireland Electricity (NIE) has some 685,000 customers (620,000 domestic, 54,000 commercial and 11,000 industrial) out of a total in excess of 710,000 customers.

10.2 Electricity Prices in Northern Ireland

Historically, wholesale electricity prices in Northern Ireland have been higher than in neighbouring markets. If one takes data from the publication *International Energy Prices* (cited in the DETI Consultation Document, Realising Our Potential), referring to prices as of the beginning of the year 2000, the following picture emerges:

1. For domestic consumers, and taking the price of electricity inclusive of VAT:

    a. Only two countries, and one region of Germany, had higher electricity prices than Northern Ireland (see Figure 19);

    b. The percentage price differential (between Northern Ireland and a given country) expressed as a percentage of the electricity price in that country, varied between -23% to +100%. Typically, Northern Ireland domestic consumers paid around 20% more for electricity than other EU citizens.

2. For industrial consumers, and taking the price of electricity inclusive of non-recoverable taxes:

    a. Only Austria and one region of Germany had higher electricity prices; and

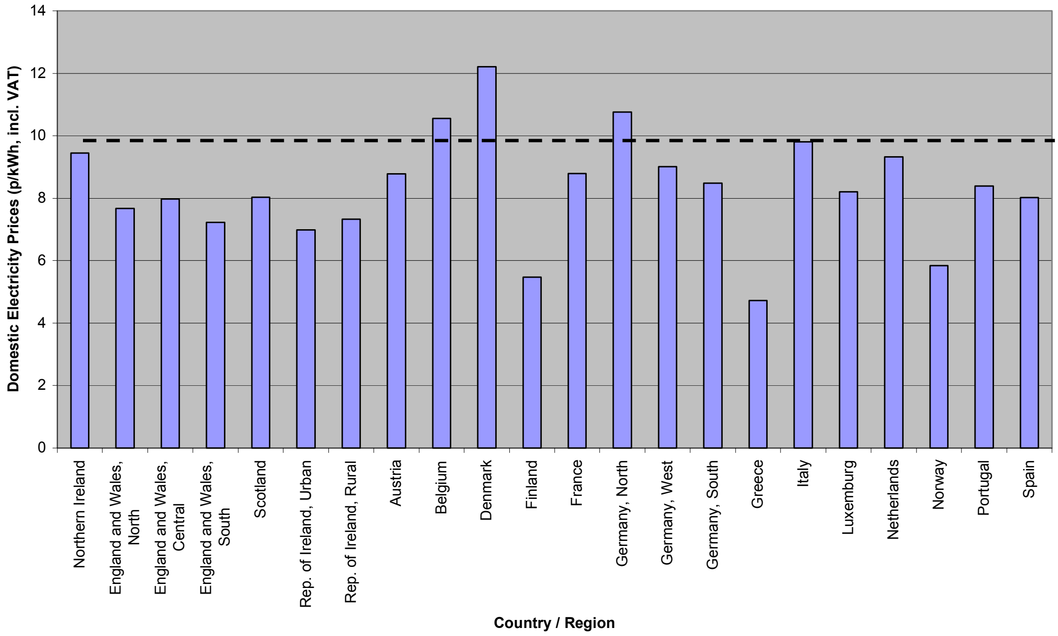
    b. The percentage price differential (between Northern Ireland and a given country) expressed as a percentage of the electricity price in that country, varied between -15% to +118%. Typically, Northern Ireland industrial consumers paid around 40% more for electricity than other EU industrial consumers.

Though the figures may have changed over time, the pattern remains the same today. Whilst acknowledging that price comparisons inevitably mask complex pricing arrangements and variations, DETI reports that on the basis of the tariffs prevailing at January 2002, electricity prices for domestic customers in Northern Ireland in 2002 were, on average:

- 26% higher than in Scotland; and
- up to 40% higher than England and Wales; and
- 26% higher than the Republic of Ireland.

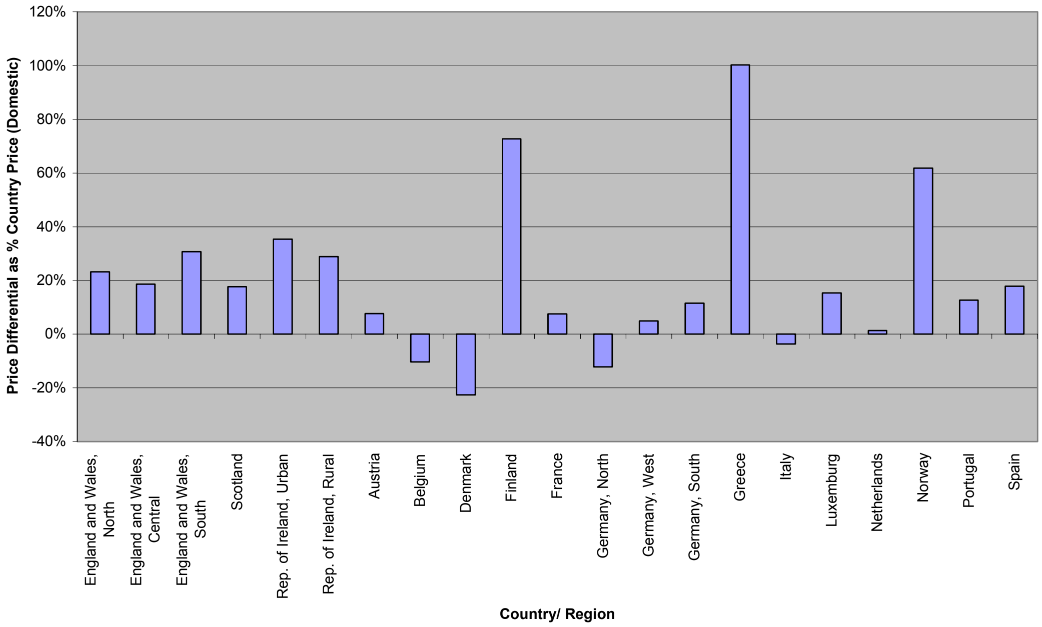
The latest available illustrative tariffs (at 1 January 2002) for industrial customers were 50% higher than Scotland, more than 50% higher than England and Wales and 2% higher than the Republic of Ireland.[45]

Figure 19: Domestic Electricity Prices, Northern Ireland and Other EU Member States (p/kWh incl. VAT)



Source: Electricity Association - International Energy Prices – Issue 27

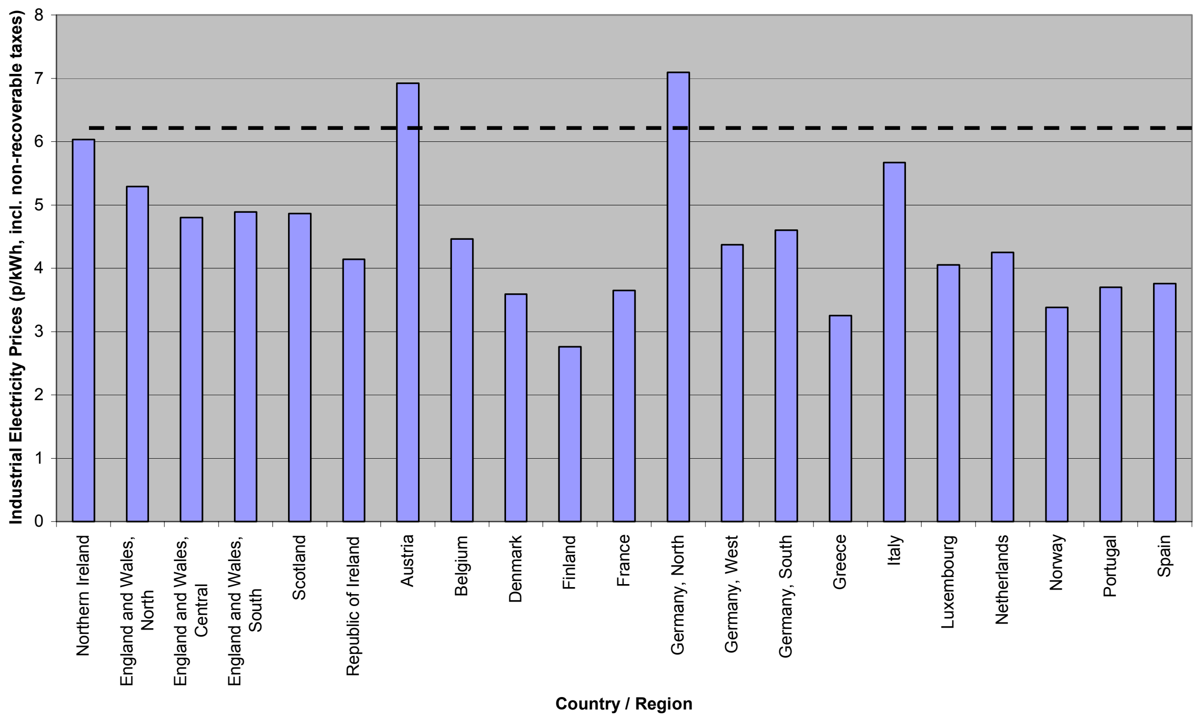
Figure 20: Northern Ireland Domestic Price Differential as % Price of Comparator



Source: Electricity Association - International Energy Prices – Issue 27

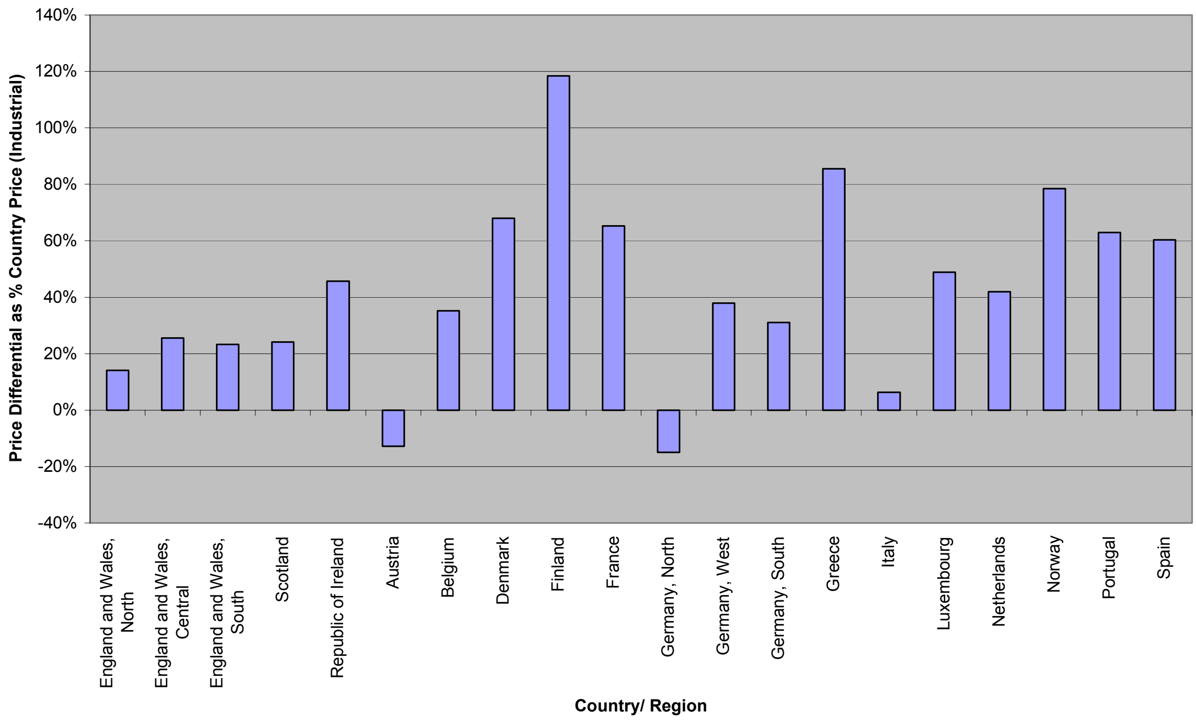
45 These figures are taken directly from DETI's website.

Figure 21: Industrial Electricity Prices, Northern Ireland and Other EU Member States (p/kWh incl. taxes)



Source: Electricity Association - International Energy Prices – Issue 27

Figure 22: Northern Ireland Industrial Price Differential as % Price of Comparator



Source: Electricity Association - International Energy Prices – Issue 27

In general, the reasons for the price differentials include:

(i) higher generation costs due to the Power Purchase Agreements put in place at the time of privatisation linked to old inefficient technology;

(ii) electricity production and distribution is more expensive in Northern Ireland than in most regions in Great Britain because power stations are smaller, the level of required back-up ('spinning reserve') is higher and customers are more dispersed; and

(iii) the divergence between transmission and distribution costs (approx 15% of final bills) in Northern Ireland and Great Britain has increased since privatisation.

Throughout the EU, the issue of 'electricity prices' is the source of a range of tensions:

- On the one hand, industrial interests argue for low prices on competitiveness grounds. The quest for low prices is often given further impetus by regulators seeking to ensure that the potential for generating rents on the part of suppliers is kept to an acceptable level, seeking to ensure that the market is competitive (and the liberalization of energy markets has been an important factor), and ensuring that low income householders are not harmed by the cost of energy. DETI lists a range of actions which have been taken to reduce prices recently:

    i. The opening of the electricity market to competition for the 750 largest (mainly industrial) customers (35% opening) allowing these customers to buy their electricity from a number of suppliers;

    ii. The Regulator has recently published for consultation a paper "Competition and Customer Empowerment" in which, in the context of further market opening, he seeks to identify the options for cutting electricity prices, focusing particularly on increased competition in the area of generation. This consultation exercise will complement the work being undertaken by the economists' group and the Department will continue to work with the new Northern Ireland Authority for Energy Regulation to achieve these objectives in the most efficient and practicable manner.

    iii. Viridian Group PLC sold the Moyle Interconnector to a not-for-profit company, Moyle Holdings Ltd, on 14 April 2003, which will reduce customers' bills by around £3m per year for the next four years and by around £1m per year thereafter. Anecdotal evidence suggests that the commissioning of the Moyle Interconnector from January 2002 has led to average savings of some 10% compared with Bulk Supply Tariff for eligible customers.

    iv. Agreement between the Regulator and Northern Ireland Electricity (NIE) on the transmission and distribution price control review will lead to an 8% reduction in the average domestic bill by 2007.

    v. The Regulator is continuing discussions with the generators on generation cost reductions (generation costs account for 80% of industrial bills and 60% of domestic bills). The efforts have been partially successful - NIE and BG International have agreed a revised contract for Ballylumford.

    vi. The proposed extension of the natural gas network to the North West which will create downward pressure on prices through reduced generation fuel costs of the new Coolkeeragh CCGT Power Station.

vii. The allocation of the £40m balance in the Government Support Fund to buy down availability payments under Ballylumford and Kilroot contracts (equivalent to 1% reduction in average bills over 10 years).

viii. The Department is keen to promote further use of Combined Heat and Power (CHP), particularly with the increasing availability of natural gas.

- On the other hand, higher electricity prices can incentivise investments in energy efficiency, whilst it also improves the prospect for market penetration by renewable technologies. Hence, DETI notes (after listing measures to reduce prices):

  i. Finally, customers can do more to reduce their bills by using energy more efficiently. There is a continuing campaign - both by Invest Northern Ireland in the industrial and commercial sectors and by the Department for Social Development in the domestic sector - to promote greater energy efficiency.

Hence, it is increasingly common to see measures designed, simultaneously, to make energy more and less expensive. The issue for policymakers is to ensure that the balance of measures to increase prices (for environmental reasons) and those to keep prices lower (for competitiveness / consumer reasons) is correct, and that the instruments achieve what they achieve for the right reasons.

10.3 Renewable Energy in Northern Ireland

Other things being equal, the higher wholesale electricity price in Northern Ireland would be expected to be a positive factor in the context of the development of renewable energy in Northern Ireland. The issue for most renewable energy sources is one of whether the mechanisms used to support the price of energy from renewable sources is sufficient to make such supplies competitive in the market for electricity generation (and supply).

The rationale for such price support (whatever the instrument may be) is that the external costs of power generation from fossil fuels is not internalized into the price of these energy sources. These external costs include those associated with greenhouse gas emissions. Here, one can note the role of fiscal instruments such as the Landfill Tax (whose original intent was to internalize the costs of, amongst others, fugitive methane emissions) and the Climate Change Levy, which is clearly intended to address (however imperfectly) the emissions of greenhouse gases from fossil fuel power sources.

To drive the process forward at the EU level, the Council issued Directive 2001/7/EC on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. This set a target for member states of 12% of electricity from renewables by 2010. It set indicative targets for individual Member States. The UK indicative target is 10% by 2010. These are not binding. However, some form of support for renewables is expected to be in place.

DETI in Northern Ireland has already consulted on the development of a policy on renewable energy. The Consultation Document, *Renewable Energy in Northern Ireland: Realising the Potential*, was released in October 2001, and it raised a number of questions. The consultation period ended in January 2002, and a report concerning these responses has been prepared.[46] It seems likely that as a consequence of this consultation (and more general deliberation), the Northern Ireland Government will come forward with legislation which is similar to the Renewables Obligation in England and Wales (which was, in effect, DTI's response to the Directive by way of a measure to meet the indicative targets in the EU Directive). Another consultation paper was issued in April 2004. In the meantime, DETI is working with DTI to change the Energy Bill to enable the new legislation to come into force. Discussions with

[46] DETI (undated) Realising the Potential: Analysis of Responses, Belfast: DETI.

DETI officials suggest legislation will be in place to enable the Obligation to start from April 2005. The Government has suggested a target level of 12% of power usage in Northern Ireland to be from renewable sources by 2012.

In what follows, and in the rest of this document, we assume that the Northern Ireland approach will be broadly as the English approach (as set out in The Renewables Obligation Order 2002).[47]

10.4 Waste Management and a Renewables Obligation

Whilst generally, the issue for a given renewable energy technology might be 'how does it compete in the market for energy supply?', when we come to waste management, the picture is far more complicated. Waste managers effectively have to choose between competing options as to how to treat the materials they have to deal with. Some of these generate renewable energy, others do not.

This choice is influenced by, amongst other things:

- Regulatory issues;
- National, regional and /or local targets;
- Anticipated future legislation;
- Environmental concerns; and
- Costs.

Policies in respect of renewable energy have at least two effects:

1. To the extent that targets are set, and to the extent that these targets are cascaded down to regional and /or local government (and in England, regions have generally set their own targets for renewable energy), the targets concentrate the minds of regions and local authorities on seeking to provide, and to plan, for the development of renewable energy sources. This means that other things being equal (and it is very important to state clearly and boldly at this point that they rarely are), waste management options which generate renewable energy will find greater favour than those which do not; and
2. To the extent that renewable energy policies support some waste management options rather than others, the relative costs of the competing options changes.

Neither of these effects can be said, in the general case, to be unequivocally positive. Rather, as the theory of the Second Best suggests, internalizing some externalities rather than others potentially distorts decisions and worsens the position of what might otherwise be considered 'superior options'. The most obvious demonstration of this doubled-edged effect comes through consideration of the energy embodied in materials themselves. Because support mechanisms focus attention on 'energy delivered', the potential energy savings from recycling (associated with capturing energy embodied in materials) go unnoticed. This has the effect of distorting waste management decisions, effectively reducing the costs of technologies generating energy, many of which treat residual waste only, potentially at the expense of what may be superior recycling options. We have discussed this elsewhere.[48]

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[47] Statutory Instruments 2002 No.914, Electricity, England and Wales, *The Renewables Obligation Order 2002*.

[48] See D. Hogg and J. Hummel (2002) *The Legislative Driven Economic Framework Promoting MSW Recycling in the UK*, Final Report by Eunomia Research & Consulting for the National Resources and Waste Forum,

To a degree, the potential for such perverse effects was explicitly acknowledged in the Directive (2001/77/EC) on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. The pre-amble to the Directive states that:

> *Where they use waste as an energy source, Member States must comply with current Community legislation on waste management. The application of this Directive is without prejudice to the definitions set out in Annex 2a and 2b to Council Directive 75/442/EC of 15 July 1975 on waste [as amended by Decision 96/350/EC]. Support for renewable energy sources should be consistent with other Community objectives, in particular for the waste treatment hierarchy. Therefore, the incineration of non-separated municipal waste should not be promoted under a future support system for renewable energy sources, if such promotion were to undermine the hierarchy.'*

It is important to note that under Article 3 of the Incineration Directive, 'incineration plant' is defined as:

> *any stationary or mobile technical unit and equipment dedicated to the thermal treatment of wastes with or without recovery of the combustion heat generated. This includes the incineration by oxidation of waste as well as other thermal treatment processes such as pyrolysis, gasification or plasma processes in so far as the substances resulting from the treatment are subsequently incinerated.*

One would expect, therefore, to see such technologies, as well as landfill, excluded from any support measures. However, in the England and Wales Order, only certain forms of incineration are ruled out of the support mechanism.

10.4.1 The England and Wales System

The support mechanism is effectively a system of tradable certificates. Hence, paragraph 3 of the Renewables Order states:

> *- (1) The renewables obligation is that, subject to paragraphs (3) and (4) and article 7, each designated electricity supplier shall before each specified day produce to the Authority evidence showing -*
>
> *(a) that it has supplied to customers in Great Britain during the obligation period to which the specified day relates such amount of electricity generated from eligible renewable sources as is determined under article 6; or (b) that another electricity supplier has done so (or that two or more others have done so); or (c) that, between them, they have done so.*
>
> *(2) The evidence referred to in paragraph (1) is certificates issued by the Authority under section 32B of the Act, provided that such certificates relate to electricity generated from eligible renewable sources.*

In determining the eligibility of renewable sources for tradable certificates, or ROCs, the Order states the following under Section 8 (para.3):

> *3) A generating station shall be an excluded generating station in any month during which it is fuelled wholly or partly by waste unless -*

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www.nrwf.org; D. Hogg (2003) *Money to Burn: Government Subsidies for Energy from Waste*, Final Report to Friends of the Earth, January 2003.

> *(a) the only waste used as fuel by the generating station in that month is biomass; or*
> *(b) all the waste which is not biomass which is used in that month by the generating station to generate electricity has first been manufactured into fuel which is in either a gaseous or liquid form (or both) by means of plant and equipment using advanced conversion technologies only.*

For the purposes of the order, the term advanced conversion technologies means gasification, pyrolysis or anaerobic digestion, or any combination thereof, and 'anaerobic digestion' is defined as 'the bacterial fermentation of organic material in the absence of free oxygen'. The first point to be made, therefore, is that AD is eligible for ROCs (Renewable Obligation Certificates).

However, there is no clear distinction between AD processes which recover materials and those which do not. Hence, there is some concern that the Order does not fully respect the waste management hierarchy, and certainly not a hierarchy which may be amended following rulings in the European Court of Justice concerning the Transfrontier Shipments of Waste. As importantly, some forms of what is defined as incineration under the Incineration Directive are eligible for support. Again, this seems inconsistent with the spirit of the Renewables Directive. In any case, the Incineration Directive requires that:

> *the heat generated during the incineration and co-incineration process is recovered as far as practicable e.g. through combined heat and power, the generating of process steam or district heating;*

To the extent that this is a requirement under the Incineration Directive (i.e. incinerators which do not comply with this are non-compliant with the law), what the ROCs system offers is support to a process – energy recovery - which is a requirement of the legislation. Notwithstanding these points, and although on the surface, application of this definition of 'Incineration' to the Directive on Renewable Energy would appear to leave the England and Wales system in conflict with the Directive, the England and Wales system was approved by the European Commission.

DTI's assumption appears to be that these technologies are best 'trialled' using 'low cost fuel' (i.e. prior to development for applications in the field of biomass generation). This too appears a questionable rationale. Experience thus far with the application of pyrolysis and gasification technologies to the treatment of mixed waste streams suggests that the problems in application lie as much with the heterogeneity of the feedstock (hence the tendency, in more advanced situations, towards the use of these technologies alongside mechanical biological treatment, or other forms of pre-treatment) as with the technology itself. Indeed, from a technological perspective, pyrolysis is already well-developed. It could be argued that using mixed waste as a barometer for the development of e.g. gasification technologies is likely to be misleading, potentially drawing one to conclude that the technology is less well-developed than it actually is (and thus, potentially slowing down its wider application in areas where more homogeneous feedstocks could be used). Lastly, if the intention is to support the development of a technology which works, it is not clear that paying for the output of successful operation is likely to be the best way in which to further this objective (since the take up of the payments implies that what is being sought – the development of the technology - has already been achieved by dint of the support given to the output side of the operation).

10.4.2 The Potential Impact on Waste Management Decision Making

The actual impact of the Renewables Obligation depends upon how the market for ROCs develops in the coming years. This scheme, effectively a tradable certificate scheme, will determine the level of enhancement in the prices of the energy delivered by pyrolysis and gasification plants. This, together with the efficiency of electricity generation from the plants concerned, will determine the level of revenue generated from the sale of energy produced.

An indication of the maximum level of support available is effectively set by a combination of the potential for electricity generation from the non-fossil fuel derived fractions of waste, and the buy-out price for ROCs. It is possible (indeed it has already occurred) that ROCs will be traded at levels above the buy-out price, but the buy-out price gives a 'yardstick' of the available price support. The buy-out price in England and Wales was set at £30 per MWh, OR 3p per kWh in 2002 and will be adjusted in line with the RPI for each subsequent year (trades above 4p/kWh have already occurred).

10.4.2.1 Potential Impact of ROCs on Costs of Waste Treatments

The ROC buy-out price is 3p/kWh. This implies that potentially, depending upon the supply of electricity from qualifying sources of renewable energy, the enhancement for each kWh supplied may reach (but will not necessarily reach) 3p/kWh. Discussions with Amanda Macintyre of OFGEM suggest that trading of ROCs has already occurred at levels in excess of the buy-out price. This is due to the so-called recycle premium. The buyout price received by OFGEM is distributed back to the electricity supply companies in proportion to the volume of ROCs each company actually holds. This provides an incremental value to the ROC (above £30/MWh) which decreases as the target is approached. Since the price of ROCs will effectively be set in the market place, the prices will reflect the tightness of supply and demand. The discussion concerning the likelihood of targets being met tends to err on the side of pessimism.[49] Hence, it seems unlikely that ROCs will fall much below the buy-out price (if at all).

A great deal depends upon the composition of input wastes. The Renewables Order suggests that the amount of electricity eligible for ROCs will be the fraction not related to generation using fossil fuels, including fossil fuels which arise as waste, such as plastics. Composition of waste determines not only the energy generated in total, but the proportion of the total which is eligible for ROCs. Here, we assume that the calorific value of the biomass fraction is 70% of input waste for pyrolysis and gasification.[50] Hence, the output eligible for ROCs would be 70% of total electricity delivered for pyrolysis and gasification. 100% of electricity from anaerobic digestion is assumed to be eligible.

The potential revenue from sales of ROCs at the 2002 buy-out price is given in Table 17. It will be seen that some of the revenues are likely to reduce costs significantly. To the extent that some facilities may be able to partition energy derived between 'heat' and 'electrical' energy, and to the extent that there may be trade offs between the two, the ROCs system is likely to place a premium on the generation of electricity as opposed to heat. This situation, in which a large differential is introduced between the markets for heat energy and electricity, is unlikely to do much to encourage establishment of viable CHP plants. However, there are mechanisms in place to encourage this (see below).

Particularly in the case of gasification technologies, but also for some pyrolysis plants too, the effect of the ROCs system is likely to be (and indeed, already appears to be) to switch attention away from mass-burn incineration and towards newer thermal treatment technologies. AD actually fares relatively poorly. Indeed, landfills which operate at levels posited by some as best practice would benefit almost to the same degree as AD. Pyrolysis and gasification, around which there are still question marks regarding the robustness of most suppliers' technologies to the treatment of residual waste, benefit considerably from the mechanism. Not all gasification and pyrolysis plants will be eligible for ROCs – whether or not they are will depend upon whether the configuration concerned involves the fossil fuel elements being

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[49] See, for example, L.E.K. Consulting (2003) *Investor Perspectives on Renewable Power in the UK*, Report to the Renewables Advisory Board, Funded by the Carbon Trust, December 2003.

[50] The mechanism by which OFGEM calculates this is set out in '*The Renewables Obligation – OFGEM's Procedures*' which can be found on the OFGEM website. It is far from clear that this is a sufficiently rigorous testing process and without proper sampling methods for the input material, this type of approach is likely to lead to some abuse of the system. There seems to be little appreciation of issues such as seasonality of waste streams, or of the potential for simply manipulating samples. Without adequate guidance for the sampling process and its subsequent independent testing (with the independent testers also subject to scrutiny), it is entirely likely that some manipulation or selective extraction of the samples will occur so as to increase the component of the energy generated which is deemed to arise from renewable sources.

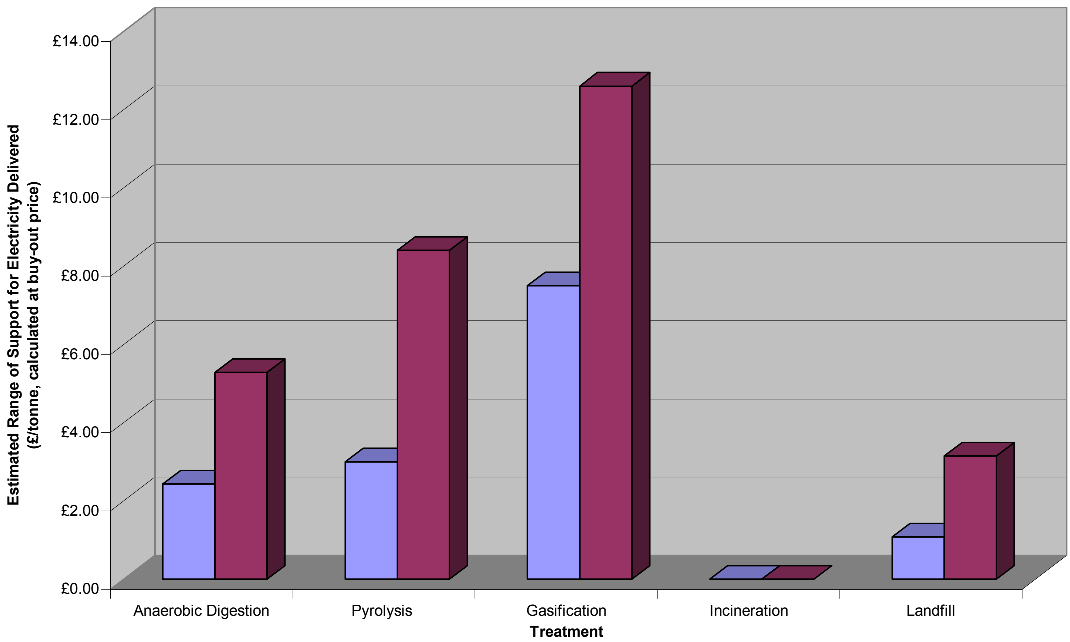
'manufactured into fuel which is in either a gaseous or liquid form (or both) by means of plant and equipment using advanced conversion technologies only'.

Table 17: Ranges of Revenue from Sales of ROCs (sold at buy-out price) by Treatment

Treatment	Total Electricity Delivered (kWh)		Revenue Per Tonne of Waste Treated From Sales of ROCs	
	Low	High	Low	High
Anaerobic Digestion	81	176	£2.43	£5.28
Pyrolysis	200	400	£4.20	£8.40
Gasification	500	600	£10.50	£12.60
Landfill	36	105	£1.08	£4.15

Source: D. Hogg and J. Hummel (2002) The Legislative Driven Economic Framework Promoting MSW Recycling in the UK, Final Report by Eunomia Research & Consulting for the National Resources and Waste Forum, www.nrwf.org.

Figure 23: High and low values for revenues from energy sales from ROCs (sold at buy-out price of 3p/kWh)



Source: D. Hogg and J. Hummel (2002) The Legislative Driven Economic Framework Promoting MSW Recycling in the UK, Final Report by Eunomia Research & Consulting for the National Resources and Waste Forum, www.nrwf.org.

The implications for AD would appear to be as follows:

1. To the extent that there are targets and measures in place to encourage source-separation of biowastes (e.g. targets for 'recycling', which include the composting and / or digestion of source-separated organic fractions), the ROCs system will encourage waste managers to digest material rather than compost it. This will be especially true where biowastes are collected such that they include catering wastes, and especially, meat;

2. If no such recycling targets are in place, the effect of ROCs may be to encourage local authorities to opt for pyrolysis and gasification of residual waste. At least, the ROCs system does more to reduce the costs of gasification and pyrolysis than it does the costs of AD. It offers no support to conventional incineration. However:

    a. There are still some concerns about the suitability of pyrolysis and gasification for treating mixed municipal wastes. Few plants can claim to show a period of continuous operation which would give comfort to waste managers;

    b. Pyrolysis and gasification are not cheap solutions. Even without ROCs support, conventional incineration may be price competitive, especially at larger scale. Equally, AD of mixed wastes may be price competitive.

Hence, the picture for AD (as regards the mechanisms to deliver Renewable Energy) is somewhat mixed. What the ROCs system does is to offer clear financial support over composting. The question remaining is whether, and if so, under what circumstances, any existing cost differential might be closed by this support. The other question is whether or not it makes sense to collect materials separately in the first place given the other options available. This issue is taken up in Section 12.0 below.

10.5 Climate Change Levy

The climate change levy imposes a tax upon industry in respect of energy use. The rates of levy are as in Table 18. The levy does *not* apply to fuels used by the domestic or transport sector, or fuels used for the production of other forms of energy (e.g. electricity generation) or for non-energy purposes. The levy does not apply to energy used by registered charities for non-business uses, and energy used by very small firms, i.e. those using a *de minimis* (domestic) amount of energy.

Table 18: Rates of Climate Change Levy applied to different fuels

Taxable commodity supplied	Rate at which levy payable if supply is not a reduced-rate supply
Electricity	0.43 pence per kWh
Gas supplied by a gas utility or any gas supplied in a gaseous state that is of a kind supplied by a gas utility	0.15 pence per kWh
Any petroleum gas, or other gaseous hydrocarbon, supplied in a liquid state	0.07 pence per kWh
Any other taxable commodity eg coal.	0.15 pence per kWh

The Climate Change Levy (CCL) specifies certain exemptions from the levy.

10.5.1 Exemptions for Energy from Waste as 'Renewable Energy'

Renewable energy sources are to be exempt from the levy. The definition of renewable sources is given as "*sources of energy other than fossil fuel or nuclear fuel, but includes waste of which not more than a specified proportion is waste which is, or is derived from, fossil fuel*". This definition is contained in clause 50 of the Utilities Act 2000.

The renewable source technologies eligible for exemption are:

1. Wind energy.

2. Hydro power *up to 10 Megawatts.

3. Tidal power.

4. Wave energy.

5. Photovoltaics.

6. Photoconversion.

7. Geothermal hot dry rock.

8. Geothermal aquifers.

9. **Municipal and industrial wastes.**

10. Landfill gas.

11. Agriculture and forestry wastes.

12. Energy crops.

Electricity is "renewable source electricity" if it is generated in a prescribed manner and the prescribed conditions are fulfilled. The prescribed conditions for Customs control purposes are set out in regulations. These include the following:

- providing renewable source declarations;
- supplying information in respect of renewable source supplies;
- facilitating the production and inspection of records relating to renewable source supplies;
- allowing entry into premises for audit purposes; and
- facilitating monitoring by the Gas and Electricity Markets Authority or the Director General of Electricity Supply for Northern Ireland, and co-operation with their authorised representatives.

In Northern Ireland, it is Ofreg that is required to supply Customs with any information that is relevant to the application of relevant provisions concerning the exemption, including CCL, Electricity and Gas legislation.

It is clear from these considerations that by virtue of being defined as 'renewable energy sources', energy derived from landfill gas and from anaerobic digestion, incineration, pyrolysis and gasification of municipal waste is exempted from the levy (as long as the electricity generated meets OFGEM standards, which leads to the issuing of an OFGEM levy exemption certificate, or LEC). It is also notable that although the role of incineration was deemed such as to make it ineligible for Renewables Obligation Certificates, no such misgivings were felt in allowing exemptions from the CCL to apply.

To bring the levy exemptions into line with the proposals under the European Directive on Electricity from Renewable Sources, the exemption is to be calculated on the basis of energy derived from biogenic wastes only. This raises interesting issues in respect of measurement which, we have noted elsewhere, are likely to give rise to issues of concern in respect of self-reporting and the associated moral hazard.[51]

10.5.2 Levy Exemptions for CHP

In the 2002 Budget, the Government announced the extension of the exemption to the Climate Change Levy to all good quality CHP (and coal-mine methane). Ofgem will be responsible for administering these exemptions and the issue of LECs for electricity generated.

In May 2002, the Department for Environment, Food and Rural Affairs (DEFRA) released a public consultation draft of its *Strategy for Combined Heat and Power to 2010*. This consultation ran until August 2002. The draft strategy highlights the various support measures available to CHP such as Climate Change Levy exemption for good quality CHP, enhanced capital allowances and VAT reduction for domestic CHP.

10.5.3 Enhanced Capital Allowances for CHP

Enhanced Capital Allowances (ECAs) are 100% first year capital allowances on investments in certain energy saving equipment. Businesses are able to write off the whole cost of their investment against their taxable profits during the period in which they make the investment. CHP is one of the eligible technologies under the ECA scheme which was introduced as part of the CCL package in April 2001.

Clearly, this is not of interest to existing plants. It is, however, of interest to new plants, and provides a useful incentive to those looking to install energy generation facilities to consider the generation of heat alongside power.

The CHP plant and machinery covered by the ECAs scheme is detailed on the Energy Technology Criteria list (see www.eca.gov.uk) and those items can qualify for an ECA if they form part of the Good Quality capacity of a CHP scheme, eligibility criteria for which was discussed above.

The administration of ECAs is the responsibility of the Inland Revenue. The Inland Revenue has recently confirmed that investment in Plant and Machinery including long-life CHP assets (assets with an economic life of 25 years or more from new) qualifies for the ECA scheme. This enables businesses to claim a larger proportion of the cost of CHP equipment against taxable profits.

In addition to being certified as Good Quality CHP under the CHPQA programme, to qualify for the allowances in respect of a CHP Scheme a "Certificate of Energy Efficiency" must be obtained from the Secretary of State. This is separate and distinct from the CHPQA Certificate. A CHPQA Certificate is required to obtain a Combined Heat and Power Certificate of Energy Efficiency. However, possession of a CHPQA Certificate does not compel applicants to obtain a Combined Heat and Power Certificate of Energy Efficiency.

CHP Guidance Note 42 states that:

'GN 42.11 *In considering the UK notification of the proposed ECA scheme, the European Commission ruled that, in the case of CHP, the award of ECAs does not constitute State Aid (and is therefore*

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[51] D. Hogg (2003) *Money to Burn: Government Subsidies for Energy from Waste*, Final Report to Friends of the Earth, January 2003.

allowable) provided that "the main intended business will be to provide heat and power for clearly identified users on site or to known third parties, and not to generate power for sale to or via unspecified third parties."

This statement is elaborated in a further reference:

"ECAs for CHP will be available for all companies except for companies whose core business is electricity production, insofar as they use the CHP system to produce electricity to be sold to unknown end users."

GN 42.12 *The statements above are clearly intended to avoid unfair competition in the Electricity Generating Industry between Member States. They should not affect the vast majority of CHP Scheme operators in UK however and provided that applicants can demonstrate their intention to supply heat and power to known end users they should fall outside the exclusion.*

GN 42.13 *Such intention is recorded in the CHPQA Form F3, which asks for details about intended power exports. It should also be in the financial interests of the Scheme once in operation, since direct sales of CHP Qualifying Power Output to end users are exempt from the Climate Change Levy.*

GN 42.16 *The Threshold Criteria for ECA eligibility are based on the CHPQA Threshold Criteria for Good Quality CHP for Proposed New Power Generation Capacity as set out in the CHPQA standard, Issue 1, November 2000.'*

From these statements, it seems less than clear whether new energy from waste schemes would benefit from the ECAs unless they supplied energy to specific end users. A more lax interpretation might be that such schemes would be eligible. Indeed, the same *Guidance Note* goes on to consider eligibility criteria for ECAs. For new or upgraded schemes that burn a proportion of biomass or solid or liquid waste fuels, the Threshold Power Efficiency Criterion is relaxed (from that which applies in defining GQCHP – see above) in the manner shown in Table 19 below.

Table 19: Threshold Power Efficiency Criterion for ECAs

	QI Threshold	**Power Efficiency Threshold**
All new or upgraded Schemes **Except** for the special cases below	≥105 under annual operation &	≥20% under annual operation
	OR ≥110 at MaxHeat &	≥35% under annual operation
New or upgraded Schemes that use **only** biomass or solid or liquid waste fuels	≥105 under annual operation &	≥10% under annual operation
	OR ≥110 at MaxHeat &	≥10% under annual operation
New or upgraded Schemes that use part biomass or solid or liquid waste fuels (See note below)	≥105 under annual operation &	≥(20 – 10 x Fw) % under annual operation
	OR ≥110 atMaxHeat &	≥(35 – 25 x Fw) % under annual operation

Note: Fw = fraction of total energy inputs as biomass plus solid waste plus liquid waste fuels

This implies that to the extent that one considers that EfW schemes are not excluded through State Aid rules, energy from waste schemes generating CHP would always qualify for the ECAs. These ECAs are claimed in the same way as other capital allowances on the Corporation Tax Return for companies and the Income Tax Return for individuals and partnerships.

10.5.3.1 Value of ECAs to Energy from Waste Operators

Under normal accounting procedures, capital allowances allow the costs of capital assets to be written off against a business's taxable profits. They take the place of depreciation charged in the commercial accounts. Commercial depreciation is not allowed for tax. The main rates of allowances for expenditure on plant and machinery are: -

- 25% a year on the reducing balance basis for general spending on plant and machinery
- 6% a year on the reducing balance basis for plant and machinery with a useful economic life when new of more than 25 years (long-life assets).

ECAs, or first-year allowances as they are also called, refer to specially increased rates of allowances. They allow a greater proportion of the cost of an investment to qualify for tax relief against a business's profits of the period during which the investment is made. They bring forward the time tax relief is available for capital spending.

It is difficult to gauge the degree to which this measure implies a level of subsidy to a given scheme without closer investigation into the specifics. In recent work for DTI and DEFRA carried out by Cambridge Econometrics, the measure was represented by assuming that the benefit would be equivalent to 10% of capital expenditure on CHP equipment. This measure proved to be one of the most significant of the Government's new measures in bringing forth CHP capacity (along with the CCL exemptions).[52]

Elsewhere, we estimated the effect of ECAs for CHP equipment as applied to incineration.[53] We based this on a 1995 study which looked at plant of 100ktpa, 200ktpa and 400ktpa respectively.[54] Gate fees were calculated for both plant supplying electricity only (450kWh/tonne), and plant supplying combined heat and power, the results were as shown in Table 20.

Table 20: Gate fees for different incinerator capacities and electricity prices

	Gate Fee					
	100ktpa		200ktpa		400ktpa	
	Elect	CHP	elect	CHP	elect	CHP
Pool price (2.5p)	47	52	36	40	28	31

Source: N. M. Patel and I. R. Higham (1995) Municipal Solid Waste Combustion: Economics and Projections for Energy Recovery to the Year 2000, October 1995.

The capital expenditure on heat export facilities was estimated at £5.2m, £8.8m and £13.7m for plant of 100ktpa, 200ktpa and 400ktpa, respectively, around a sixth of total capital expenditure. If the Cambridge Econometrics assumption is used, then the benefit of this exemption is equivalent to approximately one sixtieth of the total capital expenditure on an incinerator.

One might suppose that the lower unit capital costs of AD facilities, as well as their lower scale (and hence, the relatively increased significance of CHP equipment in the overall capital spend) might make the ECA more significant than in the incineration case. However, if one worked on the basis that the ECA was equivalent to one twentieth of the capital cost, the overall economics of the plant might not be

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52 Cambridge Econometrics (2002) *Modelling Good Quality Combined Heat and Power Capacity in the UK to 2010*, Final report to DTI and DEFRA, May 2002.

53 D. Hogg (2003) *Money to Burn: Government Subsidies for Energy from Waste*, Final Report to Friends of the Earth, January 2003.

54 N. M. Patel and I. R. Higham (1995) *Municipal Solid Waste Combustion: Economics and Projections for Energy Recovery to the Year 2000*, October 1995.

drastically effected, though evidently, it may provide a significant 'leg-up' for new facilities (and would certainly be expected to influence the decision to install, or not, CHP equipment where the potential demand for heat is not obviously 'year round'. In addition, it could be argued that new facilities ought to be under increasing pressure to recover heat. Under EU legislation, as far as other facilities are concerned, both the Incineration Directive and the IPPC Directive make it clear that heat should be recovered as far as possible from all installations (though one might comment that this has not been given adequate expression in the UK context).

10.6 NIE Support Mechanisms

NIE Transmission & Distribution, (the network operator) has expressed an interest to make support available. By reducing demand on the transmission and distribution system, embedded renewables offer the potential to reduce the need for NIE to spend on the enlargement of its network infrastructure.

NIE has initiated its SMART (Sustainable Management of Assets and Renewable Technology) programme.[55] The SMART programme comprises two primary elements:

- **SMART 1 Funding for renewable technology**
  Funding of up to £250K per annum to support "pump priming" of near-market renewable technologies and energy efficiency measures.

- **SMART 2a Funding for network support**
  Funding to support demand side management and non-intermittent renewable energy generation projects that have the potential to support and reinforce NIE's electricity network.
  The types of technologies which will be considered include biomass, solar water heating, photovoltaics (PV), ground source heat pumps, micro-combined heat and power (CHP) and small-scale hydro. We take biomass to include AD in this context.

10.6.1 SMART 1

NIE states that the SMART 1 funds are available for:

> *the 'pump-priming' of near-market renewable energy and demand-side management technologies, such as biomass generation, photovoltaics and small-scale combined heat and power.*
>
> *NIE is particularly keen to work with developers in both the private and social housing sectors to encourage low energy design and the integration of renewable energy technologies into new-build properties. We are especially interested to hear about projects with genuine educational or community value.*
>
> *The types of technologies we will consider supporting include biomass, solar water heating, photovoltaics (PV), ground source heat pumps, micro-combined heat and power (CHP) and small-scale hydro. Wind power projects will not be considered under this programme of funding.*

Several projects have been approved for funding through the SMART 1 Programme. The cases on the SMART website are mostly related to solar heating and to micro-CHP installations, the focus being on very local improvements in communities.

[55] For information on the programme, visit www.niesmart.co.uk.

10.6.2 SMART 2a

Possibly more relevant to new AD installations is the SMART 2a Programme. Here, the aim is to support parts of the grid which are weak with renewable energy installations. NIE's Transmission and Distribution business effectively has an agreement with the Electricity Regulator which gives incentives for NIE to encourage and invest in near market renewable technologies and non-intermittent renewable generation and good quality combined heat and power (GQCHP). Essentially, investing in renewables and GQCHP for network reinforcement helps fulfil the dual objectives of more secure energy supplies, and the renewables targets set by DETI.

Because the intention is to focus on network reinforcement, the support is contingent upon the location of a specific project. Some key locations for the coming years are signposted on the NIESMART website. The majority at present are in Antrim, but there are sites in all regions outside the Belfast area. The map highlights the level and broad type of supply being sought. It also aims to provide details of what would be expected from the generator in terms of availability and remote scheduling.

NIE intends to seek firm proposals against each opportunity following discussions with interested parties. The proposals will be assessed against the level of network security provided and any societal benefits such as reduced carbon emissions and employment secured. There is no hard and fast rule as to the level of support that might be available (this being related in part to the quality of the proposals in meeting the various objectives).

NIE may, on the basis of the assessment, offer a proposed renewable generator or CHP owner a Network Support Contract and financial incentive. The contract would include, among other items, agreements on the levels of generator availability, reliability and capacity scheduling arrangements. The incentive may take the form of an initial capital contribution followed by annual payments subject to contract. The level of incentive will be by negotiation and will be based on a number of factors that will include the cost of the conventional reinforcement that is avoided.

10.7 Summary

There are, it would seem, a range of potential support measures for renewable energy sources and for CHP plants in Northern Ireland. The value of these is potentially enhanced relative to other EU Member States since the wholesale price of electricity is already high. This should lead to potentially high sales values for electricity from renewable sources.

On the basis of discussions with DETI staff, and on the basis of information from the UK ROCs trading system, we would expect the following elements to determine the price received for the supply of renewable energy:

1. A wholesale price for electricity of around 4.5p/kWh;

2. An 'enhancement', likely to be at least 3p/kWh (the current buy-out price in England and Wales), related to the ROCs trading system (the Renewables Obligation). Of course, this will be market-determined. The enhancement may well be higher for two reasons;

    a. the buy-out price is linked to inflation and rounded to the nearest penny (so as soon as the RPI relative to 2002 exceeds 1.17 –by 2008 if the rate of inflation is 2.7% p.a.or greater, the buy out price will reach 4p/kWh;

    b. ROCs already trade above the buy-out price. To the extent that the market remains tight, the possibility remains that 'above-buy-out-price' trades will continue; and

3. The exemption from the CCL may be worth 0.47p/kWh in the form of LECs.

For electricity, therefore, the possibility of a net price of 8p-9p/kWh does not seem fanciful.

On top of this, AD plants which install CHP equipment may also benefit from LECs and from ECAs. These may increase the net value of these investments at particular installations.

Lastly, if plants are located in areas where NIE feels there is a need for network reinforcement, there are opportunities – subject to the plant delivering power which is not intermittent in nature – for support under the SMART 2 programme. Support is likely to be in the form of an initial capital contribution followed by annual payments subject to contract. The magnitude of this would most likely be related to the avoided costs to NIE of alternative means of network reinforcement.

This is a positive situation for the development of renewable energy in general, and for AD in particular. It suggests that, accounting for the nature of Power Purchase Agreements, and the fact that operators of AD facilities could not expect to benefit from 100% of the price to end-users, the revenue from electricity sales may be of the order 6.5p-7.5p/kWh.

11.0 PLANT ANALYSIS

11.1 Introduction

Several suppliers of AD plant were contacted for this study. A number were sent questionnaires. We sought to structure the questionnaire such that it would cover different possibilities for making use of wastes other than municipal wastes. We also felt it necessary to grant the confidentiality requests of suppliers.

The full analysis was intended to cover, for six suppliers:

- The physical characteristics of the processes (land take);
- Economics / financial viability (including, e.g. issues around selling electricity into the grid, revenues from use of residues, economies of scale);
- Cost of installation and maintenance; and
- Degree of assurance with respect to compliance with existing legislation (especially ABPR issues).

Because there were 'Northern Ireland-specific' aspects to some issues, especially in respect of the economics, it was felt necessary to keep some aspects out of the questionnaire (and to add these on 'an equivalent basis' later).

It is not the intention of the study to 'endorse' one or other technology.

11.2 Processes Covered and Pre-treatment

The processes covered included a range of systems, including dry single-stage systems operating in thermophilic range, wet single stage systems operating in the mesophilic range, wet single stage systems operating in thermophilic range, and wet two-stage systems operating in the thermophilic range.

Wet systems (approx 10% d.m.) tend to use different pre-treatment systems to the dry systems. For wet systems, the pre-treatment usually starts with homogenization and pulping with separation of contraries achieved by use of gravity (the inerts are trapped) and rakes (the low density materials, such as plastics, are raked off). One of the operators of a wet system suggested that there was no demand for water since water in the waste would be used. This seems unlikely given the target 10% total solids for the process. It would require co-digestion with slurries for this to be the case. Some systems offer a secondary stage of inerts removal principally for the purposes of reducing wear on the equipment from the abrasion by fine inerts.

In essence, wet systems suggested that there was little difference between pre-treatments, irrespective of whether the feedstock was kitchen and garden waste, or kitchen waste only. One supplier commented that the design of the primary shredder would need to be changed.

The dry systems (30-32% d.m.) make more use of screens and magnetic separators to remove contraries. Shredders were seen as more important for the material where it contained garden waste. For kitchen wastes, some processes made it clear that pre-pasteurization could occur (temperature-time requirements are discussed later). One operator commented clearly on the links between feedstocks and outputs: *'the composition of the input waste must fulfil the requirements for proper biology and high quality end product (compost)'*.

11.3 Physical Characteristics

11.3.1 Published Data

There is a range of published data available on the area which would be required by anaerobic digesters. The area would be expected to vary somewhat depending upon:

1. **The process efficiency**. The loading rate and the related retention time will determine how much material can be treated by a digester of a given cubic capacity. On the other hand, the digesters themselves do not always occupy a significant proportion of the area;

2. **The nature of treatment of biogas**. If this is piped off site, there might be some reduction in the area devoted to utilisation of biogas. On the other hand, the land requirements are relatively small for this, and proportionately smaller as capacity increases;

3. **The nature of treatment of digestate**. On the one hand, some less sophisticated treatments might seek to market the combined solid and liquid mass to farmers. This would be a 'low value' route, and may give rise to problems in spreading unless carefully handled. On the other hand, more sophisticated treatment of the digestate (typically, implying aerobic processes of some sophistication, using aerated floors) will necessarily require less time to stabilise the digestate than would less sophisticated systems (which in any case, will need to allow for some maturation of the resulting material).

It is quite interesting that in Table 21 below, the land requirement seems to be relatively consistent across processes and designs, partly for reasons discussed above. As long as the digester performs well, many of the other elements which determine land take are unavoidable to a greater of lesser extent.

Interestingly, there is a more or less linear relationship, reflecting the fact that the requirement for land area per tonne of capacity seems to vary around a figure of approximately 0.3 m^2/t. Interestingly, the English Environment Agency estimated this figure at 0.5m^2/t, which seems rather high.[56] This is revealed when the areas are plotted against capacities in Figure 24 (in this plot, we omitted the data related to the experimental Swedish plant). The slope of the graph (equivalent to the area per unit increase in capacity) is 0.29. The fit of the linear plot is surprisingly good. This may be co-incidental (there are many variables at work), and usually, one would expect the required area per unit of capacity to fall as capacities increase.

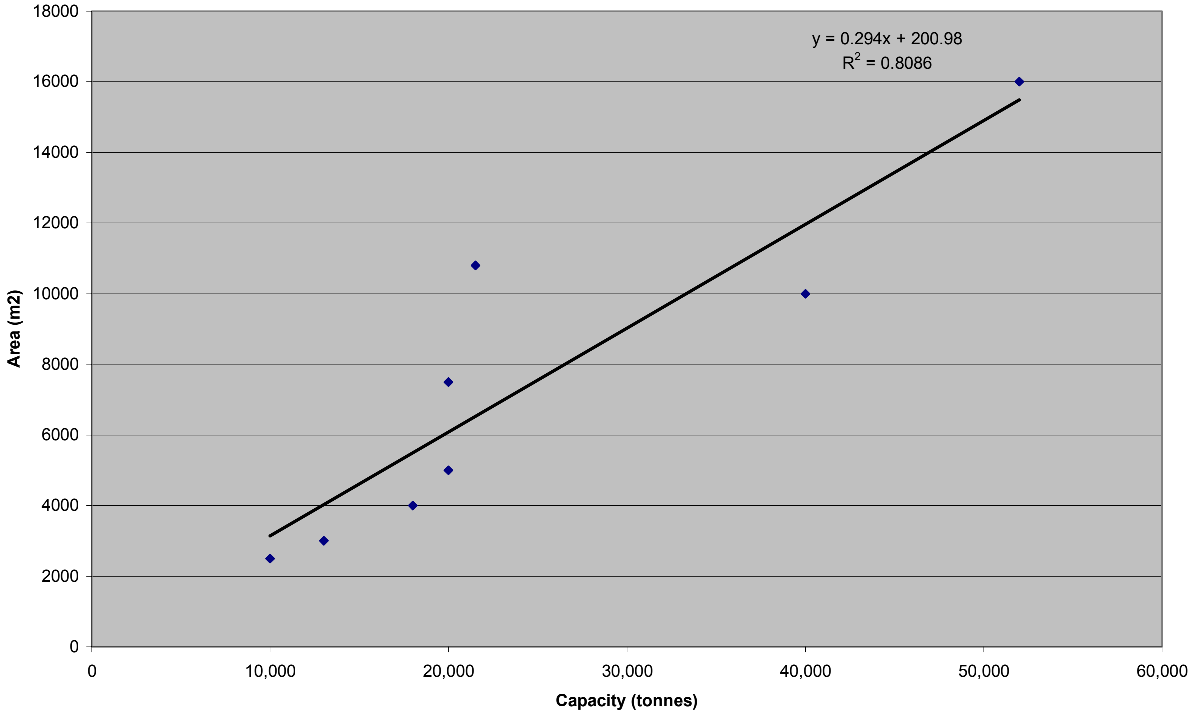
There is no obvious reason why the UK Animal By-products Regulation would significantly increase land requirements. There is a requirement to store material for eighteen days before spreading it on land, but in many cases the material is composted for several weeks. This is not always true, and the length of time for storage may have an impact. The requirement for clear and dirty areas, and for washing areas, may imply some additional area requirement, though this seems unlikely for AD plants owing to the fact that the material has a directional flow in the process.

[56] P. Wheeler, L de Rome, A. J. Poll and A. van Santen (1999) Waste Pre-treatment: A Review, Agency R&D Report Reference No PI-344/TR, Bristol: Environment Agency

Table 21: Land-take of Different Anaerobic Digestion Plants

Company	Country	Location	Type of material	Source	Capacity (tonnes)	Size (m2)	m2 per tonne	Size (ha)	Includes
Greenfinch	UK	Hypothetical		City Solutions	20,000	7500	0.38	0.75	Storage for maturation of digestate and power production
Valorga	France	Amiens	**Fraction separated from residual**	Wannholt	72000	33574	0.47	3.36	Significant pre-treatment (mixed waste) and steam generator
Valorga	Netherlands	Tilburg	Sorted kitchen and garden waste	Wannholt	52000	16000	0.31	1.60	Simple aerobic treatment of digestate in covered area with air sucked into biofilter, biogas is sent to generator at adjacent landfill site
Dranco / OWS	Belgium	Brecht	Sorted kitchen waste (17%), grass and leaves (45%) and woody material (36%)	Wannholt	13000	3000	0.23	0.30	Simple aerobic treatment of digestate and power production
Kompogas	Switzerland	Backenbulach	Sorted (50:50, kitchen:garden)	Wannholt	10000	2500	0.25	0.25	Aerobic treatment in enclosed building using forced aeration, three gas engines to produce electricity
BRV	Switzerland	Allmig/Baar	Sorted (kitchen and garden, some commercial, some manure)	Wannholt	18000	4000	0.22	0.40	Aerobic treatment (two-thirds of the plant capacity is dealt directly in this way as it is more woody in nature) and electricity production in a gas engine
Waasa	Finland	Vaasa	60% unsorted, 40% crudely sorted (optibag)	Wannholt	40000	10000	0.25	1.00	Simple outdoor storage of digestate, gas engines for CHP
BTA	Germany	Baden-Baden	Sorted kitchen and garden	Wannholt	21500	10800	0.50	1.08	Aerobic treatment using forced aeration, refinement using screens
YIT/VMT	Sweden	Sobacken / Boras	Sorted through optibag	Wannholt	8100	11000	1.36	1.10	Note - this was an experimental plant - the figures may not be applicable

Figure 24: Plot of AD Plant Capacity v Area of Land for Total Treatment



11.3.2 Plant Data Obtained for the Study

11.3.2.1 Minimum Scale

None of the major manufacturers contacted would consider installing facilities of less than 5,000 tonnes per annum. One stated that they would not consider installations less than 25,000 tonnes. This does not imply that smaller plants are 'not possible'. There is, of course, an element of bias in that the choice of possible respondents was deliberately made such as to include major suppliers of commercial scale plant. Other suppliers exist who specialise in smaller scale facilities.

This issue is of some significance for Northern Ireland. There may not be too many opportunities for facilities of large scale if they are dealing only with source separated organic fractions of municipal waste. Hence, plants of the order 10,000 tonnes may be of particular interest. The suggestion is that some suppliers will not be interested in this market. However, the range of suppliers is sufficiently large for this not to be a problem in itself (but see below with respect to costs).

11.3.2.2 Land-take

The question asked of suppliers was:

Bearing in mind the requirement to store material for eighteen days before spreading it on land, what would be the area of land required for:

a) A plant of 10,000 tonnes capacity (it will be assumed that this includes reception, pre-treatment, reactors, gas storage, treatment of residues – please state if this is not the case)

The same question was put for plants with capacity of 20,000 tonnes and 50,000 tonnes.

The area suggested by different suppliers is consistent with what is suggested in the preceding discussion. One supplier gave results which were exceptional, however. They were exceptional in that they suggested a very large area required for the process. The figures quoted by this one supplier were between 0.8-1.0 m^2/tonne capacity. Otherwise, the figures were consistent with those cited above.

11.4 Preferred Containment Method

Generally, there was a preference to accept the material 'raw' and unlined. This makes pre-treatment processes easier. Even though, for example, paper, or biodegradable starch bags can be digested in the process, the pre-treatment process has to be designed for their presence. On the other hand, some suppliers recognised that householders wanted convenience and that as a result, they would most likely want a bag, especially for kitchen wastes. The worst situation was deemed to be large quantities of plastic bags.

One supplier – of technology which was less comfortable treating kitchen wastes alone – differentiated between kitchens of catering establishments, and kitchen and garden waste from households. The supplier mentioned the desirability of having collection vehicles with mechanisms for containment of leachable residues if the material was collected without containment (directly from a wheeled bin), with the vehicle equipped for container cleaning.

Local authorities would have to weigh up the costs of container cleaning alongside the convenience of the containment system for both the plant operators, and the householders. It is unsurprising that operators want as little containment as possible, but this merely externalises costs to the local authority (container washing) and reduces the likelihood of achieving high captures of kitchen waste. Probably, an optimal system for households would make use of readily digestible containment for kitchen wastes (preferably water-tight), though possibly with larger catering establishments given unlined wheeled bins. One of the advantages of kitchen waste only systems is that the small size of the buckets for food waste makes it easier for households to carry out their own cleaning as and when necessary. Clearly, where high captures of food waste are anticipated, the vehicles need to be lined to prevent leachate spillage on roads.

11.5 Key ABPR Process Requirements

The questionnaire asked suppliers how they intended to meet the temperature-time, and particle size requirements of the UK ABPR. One operator's response was not clear on this. This was a plant operating in the thermophilic range. The ABP requires a temperature of 57^{o}C to be reached for 5 hours. In the system described, the thermophilic temperature was 55^{o}C. Such systems would need to elevate temperatures for the specified period, or carry out a pre-pasteurisation of the material (so as to constitute the first barrier). Note, a post-treatment pasteurization would probably mean that the time in the digester would not count towards the 18 day storage requirement (so this might incur additional costs if post-treatment composting were planned to take less than 18 days).

Evidently, this aspect of the legislation is controversial. As one supplier noted:

> *'There is no pasteurization pre-treatment foreseen in our process. Nevertheless, to follow this regulation we propose 2 solutions:*
>
> *To run a thermophilic mode (55C) during three weeks*
>
> *To heat the digested matter to 70C for 1 hour in tunnels during the heating stage to dry stabilise the matter as compost'*
>
> *Based on studies, hygienisation of the matter occurs when:*

- *The residence time is more than 21 days for the mesophilic mode;*
- *The residence time is more than 15 days for the thermophilic mode.'*

Note that this supplier put forward capital costs which are much higher than those quoted by other facilities. We suspect that one of the reasons for this is that the three week retention at thermophilic temperatures is likely to increase the digester volume required to treat a specific throughput of material.

Other suppliers opted for a pasteurization pre-treatment for the kitchen waste element, with the material shredded and screened to ensure the appropriate particle size reduction. One explicitly stated the intention to pasteurize material at 71°C for 1.5 hours. It went on:

> *We would only design biogas plants to the EU standards which include pasteurisation as a separate stage. Unfortunately Defra made a nonsense by not understanding the difference between biological treatment and thermal treatment, so the above table* [i.e. the Table outlining process requirements under the UK ABPR] *does not really make sense.*
>
> *There are two key reasons for adopting EU standards: first, that if the client wishes to treat non-catering waste, e.g. supermarket waste after December 2005, then it cannot be to Defra standards; second, and very important, not withstanding the Defra risk assessment the digestate still has to be free of salmonella. 4.7 log reduction is not the same as eradication, and Defra have missed this point.*
>
> *Our design is based upon meeting the regulations to an exacting standard and we have had detailed discussions with the State Veterinary Service.*

This requirement ought not to pose serious problems for most facilities. This is because the biogas is (not untypically) combusted in plants which generate heat and electricity (whether or not they are designed to deliver both). As such, some of the energy derived ought to be available for pasteurization with minor modifications.

The answers to this issue clearly illustrate the fact that UK interpretation of the ABPR has created some confusion, not least since in our experience, few operators see much logic in the process requirements as specified. This was reflected in several responses to the Consultation on Defra's proposed Statutory Instrument, including those from Silsoe Research Institute and the Danish Veterinary Institute. The latter made the point that the risk assessment carried out on behalf of Defra had probably underestimated the effects of many existing digestion systems by a factor of 10,000 or so. This is broadly the same error margin as we have suggested exists in respect of the assessment of risk associated with compost plants.[57]

Many biogas processes are presented by pasteurization (70°C / 1 h / 12 mm) in combination with either mesophilic or thermophilic digestion. This means that the pathogen reduction will be associated with two processes. In the Defra Risk Assessment, the pathogen reduction of biogas treatment is measured as reduction of faecal streptococci (FS) as described by H.J. Bendixen (DK). Using the same indicator organism it is possible to give the expected effect of pasteurization (Lund et al., 1996, Antonie van Leeuwenhoek, 69: 25-31) combined with the effect of either mesophilic or thermophilic digestion as stated in the study. These are shown in Table 22 below.

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[57] See D. Hogg (2003) *Risk Assessment and the ABPR: A Critical Review of the UK Approach*, presentation to the ECN/ORBIT Conference, Maastricht, October 2003.

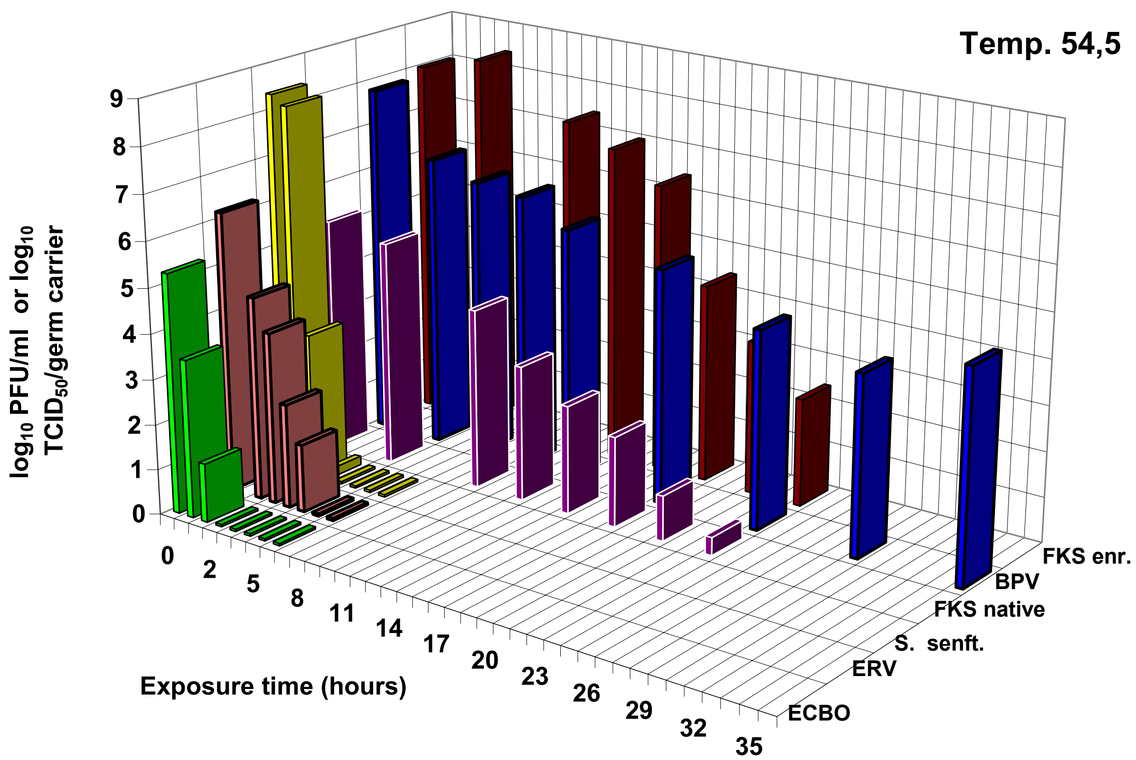
Table 22: Log Reductions of Presence of Faecal Streptococci (FS) Due to Pasteurisation, Mesophilic Digestion and Thermophilic Digestion

	log reduction of FS
Pasteurisation (70 C / 1h / 12 mm)	> 6
Mesophilic digestion	1
Thermophilic digestion	4 – 6

This means that if there is a pre-pasteurization process, the pathogen reduction of the biogas process will be between 7 log (pasteurization + mesophilic digestion) and > 10 log (pasteurization + thermophilic digestion). The pathogen reduction in the biogas process will, of course, depend on the time and temperature in the reactor but the figures mentioned here are those given in the risk assessment study.

A more sophisticated view takes into perspective the effects on different organisms of the digestion process. Figure 25 shows results of digestion processes without pre-pasteurization on pathogen elimination. Only bovine parvovirus experiences a log reduction of less than 6 when digestion takes place in standard mesophilic processes. These figures – and the fact that the Defra Risk Assessment based its whole analysis on only one study (and a limited understanding of digestion) perhaps makes the frustrations of process operators more easy to comprehend.

Figure 25: Reduction of different test germs in a thermophilic biogas plant (cattle slurry, 54,5°C; FKS: Faecal streptococci; BPV: Bovine Parvovirus; S. senft.: Salmonella senftenberg; ERV: Equine Rhinovirus; ECBO: Bovine Enterovirus)



Source: Wolfram Martens (2003) Suitability of Different Test Organisms as Parameters to Evaluate the Hygiene Effectiveness of Composting and Digestion, presentation to the ECN/ORBIT Conference, Maastricht, October 2003.

11.6 Acceptance of Different Materials

The equipment suppliers were asked what materials they would seek to co-digest if they had the choice, and what the benefits of doing so might be.

One supplier asked for paper and cardboard. It stated that this would need to be shredded to fit with the maximum particle size under the ABPR (60mm). Several digesters in Europe already target non-recyclable cardboard. The supplier commented that the cardboard increases biogas yields and reduces excess water production.

Another supplier – which had commented that it would be reluctant to treat only kitchen wastes since the stability of the process would be questionable - suggested they would seek commercial waste from food factories, plant oils, herbs, etc. with preference to storable materials. The aims would be to seek better capacity utilisation, especially in winter (when garden waste deliveries would decline), and higher gas production.

Another argued the case for co-digestion on pure economies of scale (to keep unit costs down). It felt that ideal materials were undigested sewage sludge and commercial and industrial wastes. Not all equipment suppliers were keen to accept only kitchen wastes. Commercial and institutional organic waste and undigested sewage sludge were seen as the preferred options. Co-digestion could also offer product mixing and blending possibilities to make specific products.

Other suppliers listed the following materials as suitable:

- Commercial Catering Waste.
- Retail Food Waste.
- Food Factory Waste.
- Category 3 Abattoir Waste.
- Abattoir Gutfill.
- Sewage Sludge.
- Animal Slurry.
- Wet Energy Crops, e.g. ryegrass, maize, fodder beet, lupins.

Other important rationales for co-digestion were given, including additional opportunities for gate fees, and the production of renewable energy which is non-intermittent (i.e. more constant level of generation of electricity).

11.7 Retention Times

Retention times in the single-stage systems varied between 14-25 days. The retention times were, as expected, higher for mesophilic systems. The two-stage (mesophilic) process quoted retention times of 2-4 days for the hydrolysis phase and 3 days for the methanization phase.

The retention time is significant in the context of Defra's desire to see a second barrier to ensure pathogen kill after the pasteurization process. For digestion, this is an eighteen day period of storage, which can include the period in the digester. Since the retention times are of the same order as the required storage time, then as long as pre-pasteurization occurs, the process would be deemed compliant.

11.8 Biogas Production and Energy Content of Biogas

Biogas production from the different plants are shown in Table 24. The biogas production will vary, depending upon:

- Details of the process (and the extent to which volatile solids are converted to biogas, itself partly a function of retention times and the temperature of the reaction process); and

- The volatile solids content of the feedstock (a function of the waste composition, itself varying with the seasons).

Hence, the quoted figures suggest a range which is plausible – 110-170 Nm^3 per tonne of waste input.

The energy content of biogas relates to the methane component thereof. The typical proportion of methane which is biogas varies from 55%-65% across the plants. This leads to a range of 66-100Nm^3 for methane production.

The energy content of the methane from digesters is of the order 36MJ/Nm^3. This would suggest an energy content of between 2340-3600MJ per tonne of feedstock, or 650-1000kWh per tonne of feedstock. The implied net conversion efficiencies for electricity ranged from 25%-32% (i.e. accounting for own use). This leads to net delivery of electricity ranging from 164-264kWh electricity per tonne, a very wide range.

11.8.1 Previous Studies

This variation is not inconsistent with the breadth of ranges quoted elsewhere, though the figures are at the higher end of what is quoted in other studies. This might be explained through appeal to the process improvements which have occurred over time.

Table 23 Anaerobic Digestion - Net Energy Production Figures From Various Sources (quoted in kWh per tonne of waste)

Study	Net Energy Production	
	Minimum*	Maximum*
White et al (2000)	110	
IEA Bioenergy (1997)	75	150
IWM (1998)	100	200
Waterman BBT (1999)	100	
DHV study	102	
NOVEM	21	154

**If only one figure is quoted, the study in question did not provide a range*
Sources: DHV (1997) Composting in the European Union, Final Report to DG Environment, the European Commission; IEA Bioenergy (1997) Systems and Markets Overview of Anaerobic Digestion, Washington, DC: Resource Development Associates; IWM Anaerobic Digestion Working Group (1998) Anaerobic Digestion, Northampton: Institute of Wastes Management; Novem (1992) Conversion Techniques for VGF – Biowaste: Developments in 1992, Report 9317, Haskoning (Royal Dutch Consulting Engineers and Architects), Nijmegen; White, PR., Franke, M. and Hindle, P. (2000) Integrated Solid Waste Management: A Lifecycle Inventory, Glasgow: Blackie Academic and Professional; Waterman BBT (1999) Cost of MRF and AD Plants for MSW, ETSU B/WM/00547/REP.

Other quoted estimates from a recent study are given in Table 25.

Table 24: Biogas Production in Plants

Feedstock	Kitchen and Garden	Kitchen and Garden		Kitchen and Garden		Kitchen	Kitchen and Garden
Retention Time (days)	21	16	21	14	16	25	25
Gas production per kilogram wet waste (m3 biogas/tonne input waste)	120	110	150	122	138	140	170
Methane production per tonne wet waste (m3 methane / tonne input waste)	55%	56%	62%	60%	65%	61%	59%
Methane production per tonne wet waste (m3 methane / tonne input waste)	66	75		76	86	85	100

Table 25 Net Energy Production Figures From Specific Technological Ad Processes (in kWh per tonne of waste)

Process	Net Energy Production	
	Minimum*	Maximum*
Dranco	105	157
Kompo	85	90
DBA	45	60
WAASA	120	170
Plaunener-Verfahren	85	110
D.U.T	254	292
AN-Anaerob	38	60
BTA	100	130
Prethane-Biopaq	80	140
Schwarting-UHDE	154	

Note if only one figure is quoted, no range was given.
Source: Tobin Environmental Services (1999) A Feasibility Study for Biological Treatment of Waste in the Dublin Region, Report FB\2-04, Dublin: Department of Environment and Local Government.

In previous work for the European Commission by ourselves, we used the figures shown in Table 26. These are lower than those obtained for this study. One reason for this may be that previous studies have often included centralized biogas plants which co-digest other materials, which generate less biogas per tonne than does the organic fraction of municipal waste. Evidently, the net energy delivery figures – of great importance to the economics of plants, and their environmental performance – may be higher today than they have been in the past.

Table 26: Electricity and Heat Generated from Anaerobic Digestion

Parameter	Low Value	High Value
Biogas yield	70 m^3 /t waste	140 m^3 /t waste
Percentage methane	55%	60%
Calorific value of biogas	385 kWh/t waste	840 kWh/t waste
Electricity generated (30% efficiency)	116 kWh/t waste	252 kWh/t waste
Electricity for export (70% of elec. gen)	81 kWh/t waste	176 kWh/t waste
Heat recovered for CHP option (70%)	189 kWh/t waste	412 kWh/t waste
Heat exported for CHP option (80 % of that recovered)	151 kWh/t waste	329 kWh/t waste

11.9 Material Outputs from the Digestion Process

Suppliers were asked about the cheapest option for dealing with the residues from the process, and their preferred method of dealing with them.

It is clear that the cheapest option is for spreading the digestate on land directly without any dewatering. For all but one supplier, however, some form of aerobic treatment of the dewatered substrate was the preferred option. Unsurprisingly, the supplier which did not want to dewater digestate was a supplier of a wet process. This supplier commented, however:

> *we recognise that some clients might prefer to produce a two-stream digestate in which case an additional process stage can be added.*

As regards the liquor, some of the liquor would be used in the process, but generally, it was felt that this could be used in agricultural applications. Hence, for the majority of suppliers, the preferred option is one where a solid digestate is composted to produce a quality compost, with the liquor being used in agriculture.

Typically, processes include screw presses and centrifuges for the dewatering step, and some form of aerated composting step for stabilization. The latter can occur in boxes, or on aerated floors.

11.9.1 Quantity of Residues

The quantity of residues depends partly on the dry matter content of the process. The wet systems quote in excess of 800kg of residue per tonne. The dry systems quote a lower quantity (though not by much – of the order 750kg). In the dry systems, the material is split in quite different ways. Clearly, this reflect the management of the whole process – the mass of material, the extent of degradation of volatile solids – as well as the nature of the feedstocks, and the post-treatment of the material.

The highest mass of compost per tonne of input waste also happened to be associated with the lowest biogas yield. This plant produced 500kg of compost per tonne of waste input. In other plants, more typical figures are 330-370kg of solids per tonne of input, with subsequent mass loss in the aerobic composting process resulting in 290-340kg compost. The water left after separation varied from 200l to 480l per tonne of waste. The highest liquid content was from a dry process marketing liquor to farmers. The one plant for which the preferred option was spreading of slurries on land generated 830kg of slurries per tonne of waste.

11.9.2 Quality of Residues

11.9.2.1 Physical Characteristics

The physical characteristics of the composted digestate are generally positive. One of the reasons for stabilising the solids from digestion is to reduce the potential for nitrogen to leach following application – the stabilisation process makes for an amendment with high organic matter content, but with reduced availability of nitrogen. The level of nutrients such as phosphorous is much lower than in, say, sludge based materials, making it possible to apply more organic material without creating problems of pollution.

Table 27: Nutrient and Physical Characteristics of Compost Derived from Digestate

	Dry Matter	Organic Substance	Total N	N-NO3	N-NH4	K	P	Mg	Calcium	pH
	% TM	*%TS*	*% TM*	*% TM*	*% TM*	*% TM*	*% TM*	*% TM*	*% TM*	
Supplier 1	35	72	1.71		0.03	0.33	0.45	0.45	20	7.4
	% TM	*% TM*	*% DM*	*% TM*	*% TM*	*g/kg DM*	*g/kg DM*	*g/kg DM*	*g/kg DM*	
Supplier 2	>50	<50	>1	>0.04	<0.3	10	6	6	60	8.2
	% TM		*% TM*			*g/kg DM*	*g/kg DM*			
Supplier 3	56		1.12			12.4	5.1			
	% TM		*% TM*	*mg/l compost*	*mg/l compost*	*% TM*	*% TM*	*% TM*	*% TM*	
Supplier 4	57.8		0.82	53	215	0.34	0.58	0.23	2.33	7.9

11.9.2.2 Contaminants

The quality of solid residues was given in some detail by 4 suppliers. Some gave data specific to a given plant, one gave generic data. These are shown in Table 28. The one company who preferred to spread slurry on land did not give details of the content of the slurry.

The figures are shown alongside standards under the Biowaste Directive and the PAS100. It shows that all suppliers are compliant with Class 1 of the 2nd Draft of the Biowaste Directive with the exception of two suppliers who appear to fail in respect of cadmium limit values. All are well below the WRAP PAS 100 standard.

Table 28: Levels of Heavy Metal Contamination in Compost from Digestion Residual (mg/kg dry matter)

	Zn	Cu	Ni	Cd	Pb	Hg	Cr
Class 1	*200*	*100*	*50*	*0.7*	*100*	*0.5*	*100*
Class 2	*400*	*150*	*75*	*1.5*	*150*	*1*	*150*
Stabilised Biowaste	*1500*	*600*	*150*	*5*	*500*	*5*	*600*
PAS 100	*400*	*200*	*50*	*1.5*	*200*	*1*	*100*
Supplier 1	132	56	26	1.2	72	0.15	43
Supplier 2	<200	<50	<15	<.5	<60		
Supplier 3	194	27	8	0.5	67	0.10	23
Supplier 4	180	32	8	1	97	0.15	23

In Table 29 we show some results from published sources. This is by way of illustration to show the impact of mixed waste feedstocks. The colour coding is as follows:

1. Yellow cells represent non-compliance with limit values for Class 1 under the 2nd Draft of the Biowaste Directive;

2. Orange cells represent non-compliance with limit values under the PAS 100

3. Red cells represent non-compliance with the definition of stabilized biowaste under the 2nd Draft of the Biowaste Directive.

It is quite clear that mixed waste digestion is much less likely to produce a compost capable of meeting the various standards either in, or likely to be in place in the future. This is why there is a pressing need for the definition of compost in the UK to be linked, unequivocally, to quality standards which are designed to protect soil quality.

11.10 Economics

11.10.1 Gate Fee or Costs

The information provided by suppliers varies in its quality. Furthermore, although we sought to generate consistent cost data, the cost data supplied clearly refers to different things in different cases. For example, some provided results of project financing models seeking to generate internal rates of return of the order 25%. Others have presented detailed cost data based around repayment of bank loans but with, apparently, little allowance for profit.

Table 29: Levels of Contaminants in Compost from Different Feedstocks and Technologies (mg/kg dry matter)

				Zn		**Cu**	**Ni**	**Cd**	**Pb**	**Hg**	**Cr**
Biowaste Directive 2nd Draft		Class 1		200		100	50	0.7	100	0.5	100
Biowaste Directive 2nd Draft		Class 2		400		150	75	1.5	150	1	150
Biowaste Directive 2nd Draft		Stabilised Biowaste		1500		600	150	5	500	5	600
WRAP		PAS 100		400		200	50	1.5	200	1	100
				Zn		**Cu**	**Ni**	**Cd**	**Pb**	**Hg**	**Cr**
Technology	Country	Location	Feedstock	Low	High						
MAT/BTA	Germany		Sorted	15	200	52	13	0.8	53	0.2	21
Kompogas / Buhler	Switzerland	Rumlang	Sorted	150	150	40	15	0.3	40		17
Linde	Austria	Wels	Sorted	245		91	8	0.79	65	0.2	11
Paques	Netherlands	Breda	Market waste	239		60	18	0.6	79	0.14	35
Avecon / Citec	Finland	Vaasa	**Unsorted**	750	750	330	300	1.12	200	0.95	730
Valorga	France	Amiens	**Unsorted**	533		135	52	2.5	635	1.7	292
Valorga	Netherlands	Tilburg	Sorted	19		2.7	7.6	0.5	6.7	0.1	23
Dranco / OWS	Belgium	Brecht	Sorted	99	290	35	8	.7-1.5	38-156	.1-.2	13-44
Kompogas	Switzerland	Backenbulach	Sorted (50:50, kitchen:garden)	150		40	15	0.3	40		17
BRV	Switzerland	Allmig/Baar	Sorted (kitchen and garden, some commercial, some manure)	160		53	8	0.2	28	0.11	22
Waasa	Finland	Vaasa	60% unsorted, 40% crudely sorted (optibag)								
BTA	Germany	Baden-Baden	Sorted kitchen and garden	147		38	16	0.5	39	0.27	28
YIT/VMT	Sweden	Sobacken / Boras	Sorted through optibag	230		68	10	0.4	46	0.2	13

It is important for local authorities to recognize the distinction between 'economic costs' (i.e. the resources required to pay for equipment and its operation) and the financing of a specific project designed to meet the criteria specified in a contract. One of the problems of seeking to understand what local authorities may or may not pay in the context of a specific contract for a given facility is that what is often reported in literature is economic costs, frequently assuming discount rates of the order 7% and little by way of operating profit. Obviously, such cost estimates, whilst they may be useful for standardizing costs of different treatments (and hence, for comparisons), bear little resemblance to the payments a local authority may have to make once it moves forward to a contractual situation. In such situations, suppliers will – if they are charged with operating the facility – internalize the risks associated with the project into the project costs. They will also seek to ensure a reasonable profit margin (a rate of return on the investment). Once all this is taken into consideration, the actual costs which local authorities may pay for facilities can be quite different to the underlying economic costs of the facility. This is one reason why approaches to procurement, and ownership structures, are so important in ultimately determining the payments made by local authorities to their contractors.

11.10.2 Investment Costs

Suppliers were asked about the capital costs for facilities of given sizes. The results are shown in Table 30. It can be seen that the capital costs vary enormously, rather more for a given scale plant than the operating costs. This, combined with the different ways of treating capital costs, makes it difficult to generalize concerning the costs of digestion plants.

On the revenue side, we have portrayed a pessimistic, and a more optimistic scenario. In both cases, the revenue from electricity sales dominates.

In order to gain some feel for project feasibility, we have taken the operating costs and subtracted the revenues under the different circumstances. We have then assessed what would be the payback period (on a straight line basis) at a set gate fee in order to repay the capital element. The shorter this is, the more viable the project. Many commercial operators seek payback periods of the order five years, but we have italicised those with payback periods longer than 7 years.

It can be seen that even for some of the smaller facilities, payback periods are not unreasonably long. This is especially true as the gate fee increases to the higher levels. At a £55 gate fee, only one of the facilities looks as though it is definitely a non-starter. This is the 25,000 tonne facility with an unusually high unit capital cost. Payback periods lengthen when one constrains the gate fee, and the picture becomes slightly more problematic, though certainly not unreasonable for some of the cases examined. There appears to be considerable variation across technology types.

It is not always clear, from the financial breakdowns offered, how suppliers may have accounted for UK-specific issues in respect of planning, permitting and contracting. However, in general, the analysis is broadly consistent with the quotes from some of the suppliers as to where they felt gate fees would lie. The lowest quote was a gate fee of under £40 per tonne at 50,000 tonnes per annum. The highest was £75 at the same capacity. This raises interesting questions concerning the way in which different suppliers cope with risk in putting together their projects. Differing requirements in terms of rate of return may reflect different perceptions of risk, and arguably, these should be influenced by the technology's ability to do what it sets out to do. Lower costs may reflect greater confidence in, and experience with, a technology. Alternatively, it may reflect the particular supplier's position in the market (i.e. as a pure provider of technology rather than a supplier of a complete 'solution').

Table 30: Key Financial Data for Digestion Plant

CAPACITY	10,000	20,000	25,000	50,000	50,000	50,000	75,000	165,000
Total Investment Cost	£3,130,000 (incl land lease)	£3,000,000 (excl land)	£12,680,000	£6,000,000	£17,600,000	£16,000,000	£16,000,000	£20,050,000
Unit Investment Cost	£313	£150	£507	£120	£352	£320	£213.33	£121.49
Loan Service (20 year life, 7%)	£36.51	£14.91	£47.86	£11.33	£33.23	£30.21	£20.14	£11.47
Loan Service (20 year life, 24%)	£76.15	£36.49	£123.35	£29.20	£85.64	£77.85	£51.90	£29.56
Operating Cost (excl. financing)	£271,437	£400,000	£506,000	£900,000 (e)	£786,000	£1,400,000	£1,700,000	£3,660,000
Unit Operating Cost	£27.14	£20.00	£20.24	£18 (e)	£15.72	£28.00	£22.67	£22.20
Energy (kWh /tonne)	200	250	164	250	164	190	190	190
Heat (kWh / tonne)		200	172	200	172	200	200	200
Compost (kg/tonne)	290 kg	250 kg	480 kg	250 kg	480kg	370kg	370kg	370kg
Revenues (6.5p/kWh elec, 0p/kWh heat, £0/tonne compost)	£13.00	£16.25	£10.66	£16.25	£10.66	£12.35	£12.35	£12.35
Revenues (8p/kWh elec, 2p/kWh heat, £15/tonne compost)	£20.35	£27.75	£23.76	£27.75	£23.76	£24.75	£24.75	£24.75
Payback period, Revenue Optimistic, £55 Gate Fee	6.5	2.4	*8.7*	1.9	5.6	6.2	3.7	2.1
Payback period, Revenue Pessimistic, £55 Gate Fee	*7.6*	2.9	*11.2*	2.3	7.0	*8.1*	4.8	2.7
Payback period, Revenue Optimistic, £45 Gate Fee	*8.2*	2.8	*10.4*	2.2	6.6	*7.7*	4.5	2.6
Payback period, Revenue Pessimistic, £45 Gate Fee	*10.1*	3.6	*14.3*	2.8	*8.8*	*10.9*	6.2	3.5
Payback period, Revenue Optimistic, £35 Gate Fee	*11.1*	3.5	*13.2*	2.7	*8.2*	*10.1*	5.8	3.2
Payback period, Revenue Pessimistic, £35 Gate Fee	*15.0*	4.8	*19.9*	3.6	*11.8*	*16.5*	*8.6*	4.8

11.11 Summary

The plant analysis shows considerable variability in configuration, performance, and costs. The diversity in the marketplace ought to be a positive feature as long as would-be procurers of such technology are clear about what they want.

In terms of physical performance and compliance with the UK ABPR, few plants appear to face problems, even though some appear to have issues with the hygienization requirements therein. Furthermore, digestion of source separated organic fractions of MSW can generate a high quality compost product with applications in some of the higher value added applications (partly because wet separation enables some soluble salts to be removed, reducing the salinity and conductivity of the material, making it more applicable to horticulture).

Cost-wise, there is enormous variation in unit capital costs. We used three bench-mark gate fee figures - £35, £45 and £55 (the reasons for this choice will become clear in the next chapter) – to assess financial viability. Some, though by no means all, suppliers would be able to put together projects with acceptably short payback periods with gate fees at the lower end of this range, and the prospects for doing so increase with the scale of the project. However, some suppliers would struggle to do this, and for a number of suppliers, gate fees closer to £55 per tonne, perhaps higher, would be necessary.

It is important for Northern Ireland to understand that costs are acceptable for some technologies at relatively small scales. Although there is a trend towards larger digesters in Europe (partly because of the increasing resort to digestion for treating residual waste), the Northern Ireland situation probably lends itself to smaller facilities of the order 10,000-20,000 tonnes, and possibly smaller still. Hence, it will be important to ensure, where local authorities seek to implement digestion as part of their strategy, that they seek to procure the equipment in a competitive manner. Integrating contracts across a range of treatment options may well lead to inappropriate solutions given the range of costs, and the appropriateness of one or other technology for the treatment of different types of waste.

Another strategy might be to look at those companies seeking to offer more flexible solutions to deal with both source-separated and residual fractions using anaerobic digestion. More and more suppliers are offering MBT (mechanical biological treatment)-type solutions for residual waste alongside solutions for source-separation – more modular designs could be especially interesting in this context.

Lastly, economies of scale may well be found in dealing with former foodstuffs alongside municipal wastes. This also raises interesting possibilities for local authority waste collection. The logistics of the collection of source separated organic municipal waste will be improved if organic wastes from commercial premises, hotels, catering organizations, etc. are collected alongside the source-separated organic fraction from households. Many of these institutions will be forced to find non-landfill solutions for such material in the near future as a consequence of the way the ABPR affects former foodstuffs (these cannot be landfilled from 2006 onwards).

12.0 APPROACHES TO COLLECTION OF DOMESTIC ORGANIC WASTES

Successful recycling of dry fractions and packaging materials (paper, glass, plastics, etc…) in the absence of separate collection of organics has the effect of concentrating the fermentable material inside residual waste. This is also what happens in those Districts and Countries where separation of dry recyclables is more effective than that of *food* waste. For instance, in the Netherlands and Germany, the percentage of food waste inside residual waste is often reported at 40-50%. This system would demand that frequent collection of residual waste is maintained because of the potential for odour and nuisance (especially in summer months).

Where only garden waste is collected, or where kitchen and garden wastes are co-collected, one tends to find high proportions of garden waste and relatively low capture of kitchen wastes. The delivery of garden waste is stimulated by the convenience of its collection. This may have the following consequences which, though generally ‘negative’, can be addressed:

1. A high delivery of garden waste into the collection system;

2. A disincentive to home compost (if the collection is free);

3. A high level of seasonality in the collected waste;

4. An increase in costs resulting from the high delivery of material; and

5. A failure to reduce significantly the quantity of the most odorous fraction (kitchen waste) in residual waste.

In an attempt to address such undesirable effects, more recently in Southern Europe a different scheme for the collection of compostables has been implemented, where the collection of food waste and that of garden waste *are kept separated*. One scheme has been to tackle ***only*** “food waste” as a whole (including cooked stuffs such as meat and fish), by means of *small volume* bins and buckets, whereas a different scheme tackles garden waste only.

In Southern Europe, the rationale for this distinction could be described as follows:

- **the troublesome features of food scraps** (high putrescence and moisture). This requires the adoption of specific tools, systems and collection frequencies in order to have the system clean and user-friendly. Once citizens feel comfortable with a system, the overall participation is enhanced. This leads to better quality, a higher capture of targeted material, and a reduction in the percentage of food stuffs inside residual waste. *This makes it possible to collect residual waste less frequently with fewer problems.* Analytical measurements - where a door-to-door collection is adopted - report the content of food stuffs inside residual waste at an average of 15% and sometimes even lower, which is much lower than in previous source-separation programmes adopted in ‘Central Europe’ (i.e. the low countries, Germany and Austria);
- **the different biochemical and seasonal feature of the food scraps as compared to the garden waste**. Where a collection at the doorstep for food waste is adopted, the collection of garden waste can be carried out in a different way to that adopted for food waste. This in turn makes possible an overall optimization of the scheme, as intensive features of the collection of food waste (the need to collect at high frequencies due to odour issues, and the need to use watertight bags to contain material) need not apply to garden waste. Garden waste does not require such intensive collection patterns (it does not smell, it does not attract flies and rodents in the same way, and it does not lead to rapid production of leachate – indeed, most of that

which does can be readily treated in the garden either through 'grass-cycling' or home composting).

- **the different bulk densities of garden waste and food waste**. The low bulk density of garden waste, characteristic of the material's structure, suggests the use of compacting vehicles for collecting garden waste. In the case of food waste, the high moisture content enables the use of much simpler bulk lorries *that are much cheaper at an equivalent working capacity*. This is one of the most powerful tools to optimize the operational features and costs related to systems for source separation of compostable waste.

There is now an additional rationale for the separation of kitchen and garden wastes in the UK. This relates to issues of cost and environmental performance. Since the introduction of the Animal By-products Regulation, the costs of treating garden wastes (separately) and materials containing kitchen wastes have diverged. It makes sense, because of the higher costs of treating kitchen wastes, to keep these separate from garden waste. On the other hand, it is not possible to *compost* kitchen waste on its own. This leads to a situation in which the mass of material is likely to give rise to anaerobic conditions. For this reason, it may make sense to treat kitchen wastes through digestion facilities, possibly alongside other materials (including some kitchen wastes), with garden wastes being dealt with through (cheaper) aerobic treatments.

A system which does not differentiate between food and garden waste is a system where a huge delivery of garden waste is to be expected. There is growing evidence of this in the UK, which mirrors the early experience of other European countries (Netherlands, Belgium, Austria, Germany, Switzerland). The general outcome is a high recycling rate, but the overall MSW arising figures are much higher as well. In the UK, recent work based upon a somewhat sketchy analysis of existing collection schemes incorporating garden waste suggests that an additional weight of more than 100kg per inhabitant may be expected. This occurs whether or not the collection is a separate one (i.e. if residual waste collections allow the inclusion of garden waste, the change in arisings is likely to be similarly large, though those engaged in home composting are less likely to be discouraged by the provision of such collections only in residual waste).

12.1.1 Collection Schemes for Garden Trimmings and Home Composting

Our view is that effort has to be made to find suitable systems that enable high recycling rates to be achieved without implying an increase in the overall MSW collection. It is important to note that *where there are lawn cuttings, there is a garden in which home composting could be performed*. The purpose should then be to adopt a collection system which does not make it too easy for households to deliver their garden waste. This is why it makes sense to keep the collection of garden waste separate from the collection of kitchen waste.

Nevertheless, Local Authorities have to ensure the collection of yard waste at those households who have neither the time nor the inclination to run a garden composting site. The collection of garden waste should then be run through deliveries to Civic Amenity Sites. In addition, in order to help people who find it troublesome to go to Civic Amenity Sites (for instance due to lack of space in their car, or whatever the problem) a kerbside collection can be run using a dedicated round (a 'green circuit') and at a much lower frequency of collection than that of kitchen waste (e.g. monthly, and only 'in season'). This in turn necessitates clear 'calendaring' of the relevant days.

A specific collection of garden waste enables waste managers to plan and run a system:

- which does not involve seasonal fluctuations alongside the collection of food waste;

- which has low collection and treatment costs for the garden waste itself, thanks to simplified collection and cheaper treatment costs applied by open air windrow composting plants; and
- which makes it possible to enhance home composting. As long as households are not provided with a large-volume bin, they do not find it so easy to deliver their garden waste to the collection service, and are instead encouraged to resort to home composting, or to maintain such behaviour in those many places (often the majority in rural areas) where composting has traditionally been adopted. This maintains a good balance between the delivery of yard waste to the service and the participation to programs for home composting.

Such issues have to be kept in mind especially when planning a scheme in those situations where a high percentage of detached houses with gardens can be found.

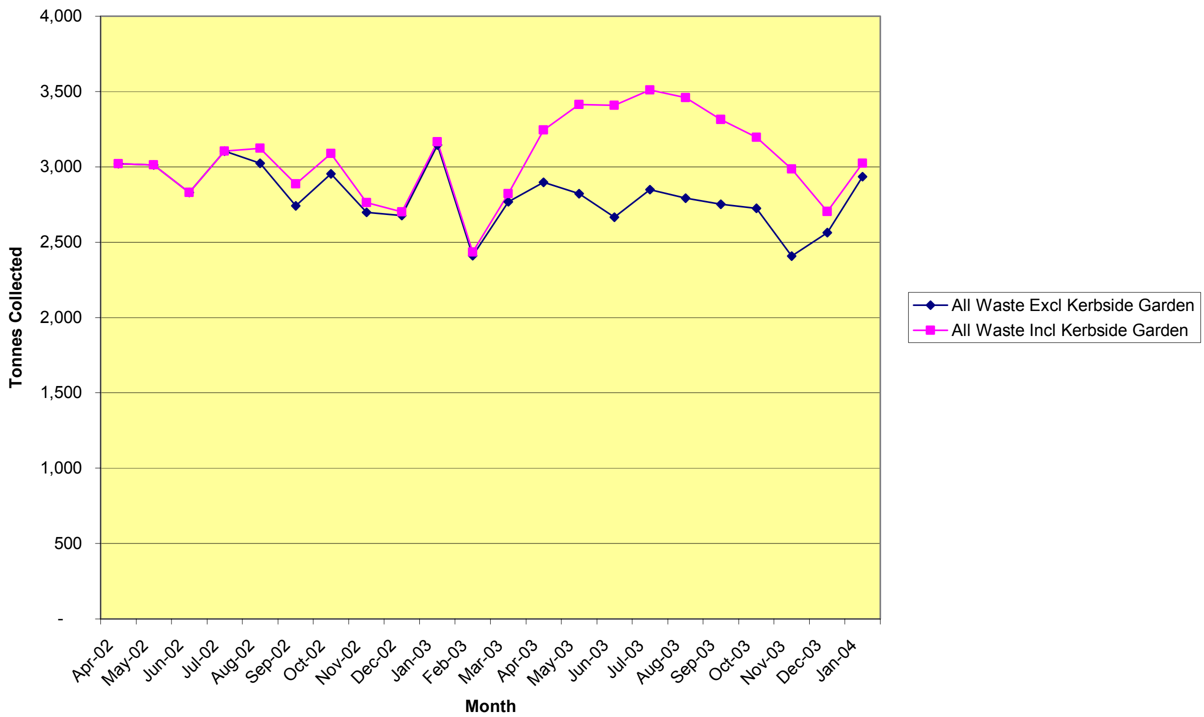
There is a question concerning the degree to which one should insist on an approach which keeps the collection of kitchen waste separate from the garden waste collection. Some have argued that where garden waste is already being collected, it may be difficult to reverse this situation. Others have argued that where refuse collections do not 'outlaw' the setting out of garden waste in refuse, the expected increase in waste arisings which might accompany the introduction of garden waste collection may not be so great (since the material is 'already there'). There seems to be some intuitive logic to these arguments. However, the statistical increase in collected waste which distinguishes wheeled bin collections from sack collections does not seem nearly as great as the changes which occur once free garden waste collections are offered.

Some justification for the view that the increase in collected waste 'is genuine' is given from inspection of specific cases. For example, in the Forest of Dean (in England), so as to try to understand the 'genuine' nature of the increase in waste collected, we plotted two quantities. The first is 'all waste collected', including all kerbside collected waste and all wastes collected at the nearest HWRC. The second is the same plot, but minus the kerbside collected garden waste (see Figure 26).

It is difficult to deny the growth in total waste collected (see also Figure 27 below). The increase varies, of course, by month. Inspection 'by eye' suggests that the total waste excluding kerbside collected green waste is, on average, around 150 tonnes less than in the absence of the scheme. A 12 month moving average for the 'gap' between the system with and without garden waste collection suggests a difference of the order 5,000 tonnes (and rising), which has been growing as the number of bins issued has increased.

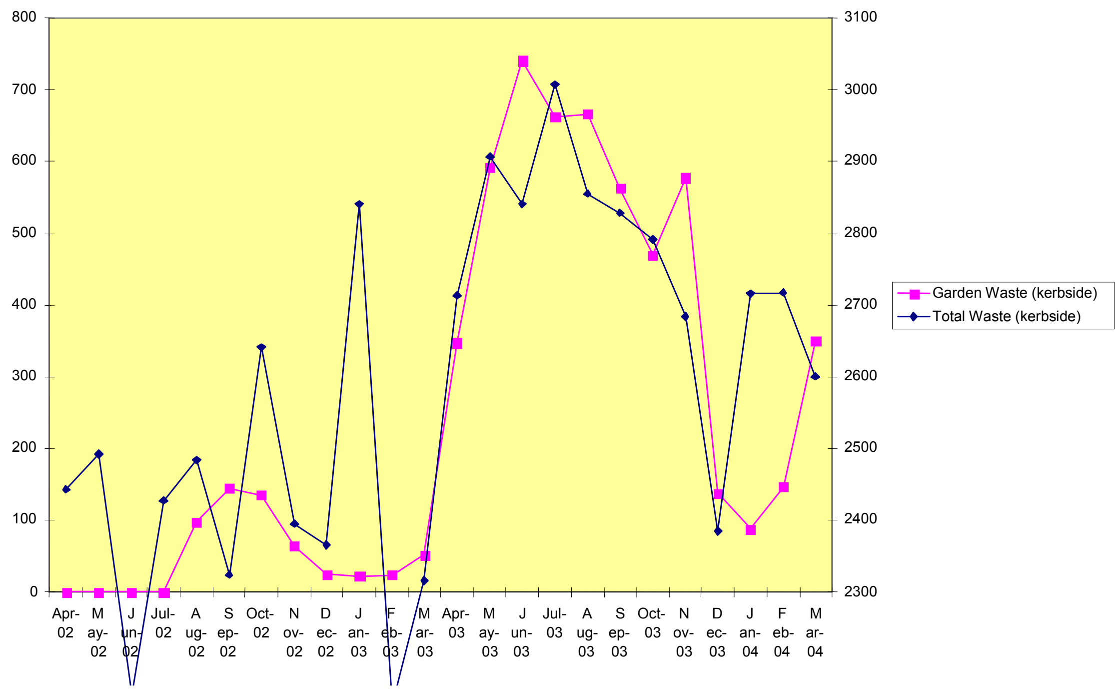
Sometimes, it is claimed that collecting garden waste does not increase the quantity of material collected but simply shifts the collected quantity from the HWRC to the separate collection system. Again, this appears to be doubtful in the case of the Forest of Dean. In the first full year of the scheme's operation, the quantity of garden waste collected at the main HWRC, if anything, increased relative to the previous year. A number of factors might explain this, including climate, and the operation of the site. Yet total waste quantities have changed little from the previous year (so it might be improved separation at the site rather than greater garden waste quantities which explain the better performance in respect of separately collected garden waste at the HWRC). The quantity of garden waste collected at the kerbside in the summer months actually approximates to the total quantity of all waste collected at the HWRC in those months. This fact simply serves to re-emphasise the 'genuine' nature of the increase in collected waste in Forest of Dean. The increase is not a consequence of a simple shifting from the HWRC into the doorstep collection. On the contrary, if anything, the deliveries to the HWRC may even have held up in the period under examination (though this is difficult to say given the influence of climate etc. from one year to another).

Figure 26: Total Waste Collected, Including and Excluding Kerbside Collected Garden Waste (Forest of Dean)



Eunomia (2004) Closing the Gap: Adaptation of Existing Systems to Improve Materials Capture, Unpublished Report to Gloucestershire County Council.

Figure 27: Kerbside Collection of Garden Waste and Total Collected Waste, Forest of Dean



Eunomia (2004) Closing the Gap: Adaptation of Existing Systems to Improve Materials Capture, Unpublished Report to Gloucestershire County Council.

In what follows, we have assumed that the objective of constraining waste arisings takes precedence over the quest for high recycling rates. Effectively, the aim is to minimise the quantity of residual waste collected. This is consistent with good environmental practice, and with the waste hierarchy.

We have also suggested, in most cases, that the frequency of refuse collection is reduced, typically from weekly to fortnightly. This not only reduces the costs of refuse collection through the frequency effect, but it is also likely to reduce the costs of disposal through improving the capture of the kerbside collections. This means that there is considerable overlap in the nature of the issues to be considered with the preceding discussion about changing refuse collection frequency.

The likelihood of an increase in collected waste occurring will probably be related to the existing modus operandi for collecting refuse, and in particular whether or not the local authority seeks to discourage setting out of garden waste in refuse, and more importantly, how (if at all) it goes about ensuring the garden waste is indeed kept out of the refuse system.

Depending upon the way in which garden waste is currently treated, there is likely to be a greater or lesser percentage of garden waste already in the waste collection system. Where the existing doorstep waste collection system effectively excludes garden waste, the introduction of a collection system which includes garden waste is likely to have significant effects on the amount of waste collected. Arguably, these are the situations in which the costs of the change which includes offering free garden waste collection are likely to be greatest. Evidently, the degree to which this is likely to be of concern will also be related to the nature of the housing stock, and in particular the presence of houses with large gardens.

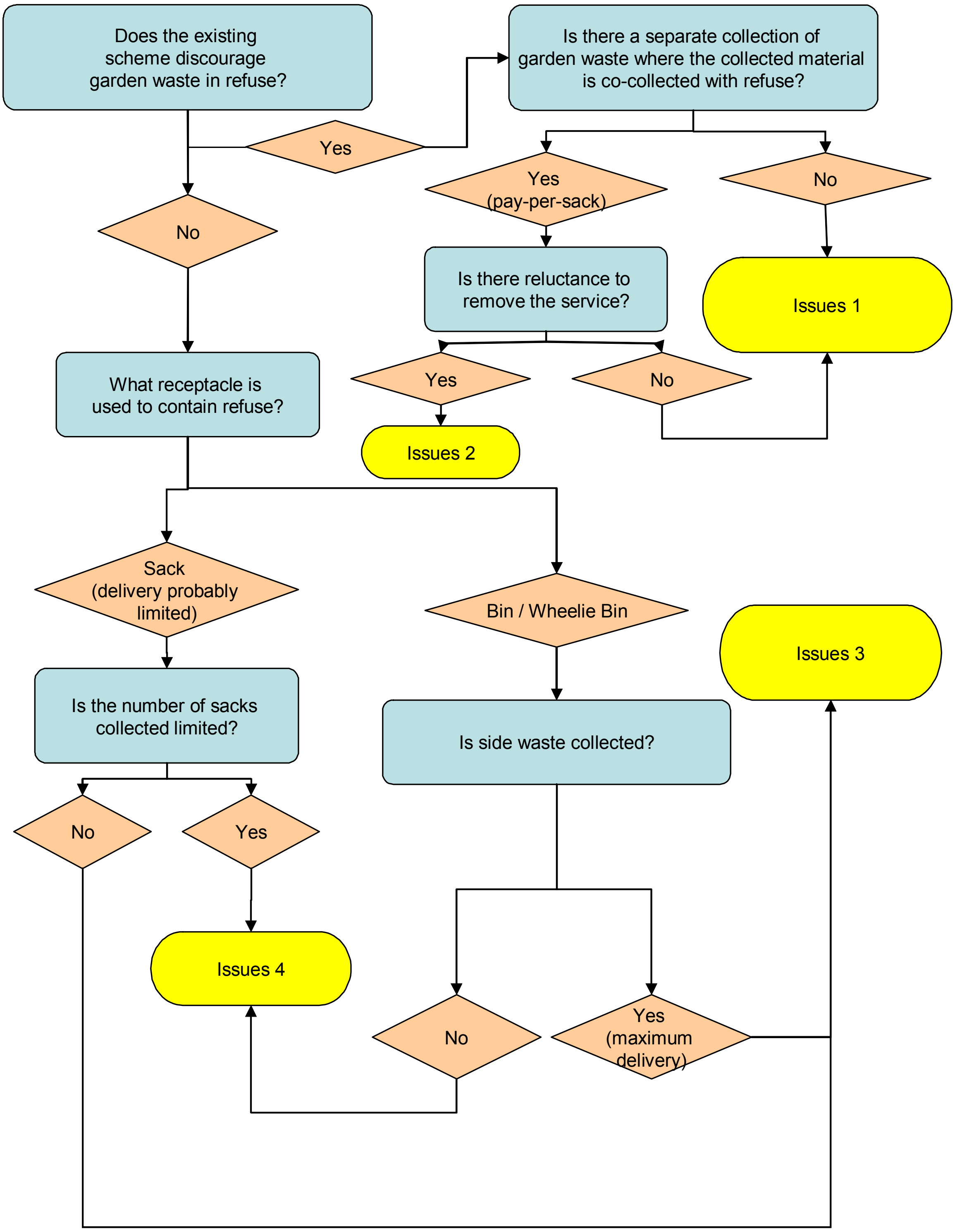
In systems which do less to prevent the delivery of garden waste into the doorstep collection system, there may be cases where the council has been effective in promoting the activity of home composting. This promotion may reduce the amount of garden waste set out for collection at the doorstep. Although the evidence to support such an assertion could not be described as being of sufficient significance statistically, there is a strong suggestion from experience in other countries that providing householders with free garden waste collections can lead to a situation where many householders abandon the practice of composting.

In cases where households live near to CA sites, then where those sites provide separate collections of garden waste, the delivery of garden waste to these sites is likely to reduce delivery into the refuse collection system. For these households, introduction of free garden waste collections may simply lead to a switch from collection at CA sites to collection at the doorstep.

The flow chart below leads to different end-points. The different endpoints are associated with different options for local authorities to consider as they plan their biowaste collections.

Issues 1:
if the refuse collection effectively excludes garden waste from the doorstep collection system, then other things being equal, there will be relatively little garden waste in the existing doorstep collections system. So as not to generate a significant increase in collecting material, this system is well-suited to one in which the bio waste collection targets kitchen wastes only, collected on a weekly basis. In a complete system, pro active approaches to promoting home composting should be in place. This is especially important in local authorities where a large proportion of households have gardens. Other ways of supporting the collection system, to enable garden waste to be dealt with effectively, might include:

Figure 3.4 Issues and Endpoints for Biowaste Collection



- Ensuring adequate provision of CA sites (both in terms of density per household, and density per unit area);
- Offering infrequent collections of garden waste in key months, preferably on Mondays following garden clear-outs. another alternative would be to operate pay per sack collections for garden waste only. These can cover their own costs;

- Running periodic chipping days, on which mobile chippers are present at pre-specified sites on pre-notified days, chipping larger garden waste items for subsequent use as mulch, either by households, or by the local authority itself;
- Establishing community compost sites across the authority to deal with garden wastes from sub-districts of the authority.

Each of these can have a role to play in a comprehensive biowaste management system.

If the option of kitchen waste only collections is chosen, consideration of the nature of the treatment facility required has to take into account the relative proportions of kitchen and garden waste likely to be available. Because kitchen wastes tend to be wetter than garden wastes, where aerobic treatment facilities are used, it is more likely that they will need to be dynamic in nature (i.e., they should make use of some form of turning equipment). In addition, attention needs to be given to the pre-treatment process. Again, kitchen waste, being wetter than garden waste, presents different problems in terms of mixing and shredding. Alternatively, keeping kitchen wastes and garden wastes separate offers the possibility to treat garden wastes through low-cost open-air windrow systems, with the wetter kitchen wastes being dealt with through anaerobic systems. Again, the choice of anaerobic system has to take into account the nature of the wastes being processed. Irrespective of whether aerobic or anaerobic systems are chosen, it may well make sense to consider other wastes available for processing through the facility. This may be particularly relevant given the requirement for former foodstuffs to be dealt with through means other than landfill in the future.

Issues 2:
in this case, there is an existing collection system for garden waste in which households pay, typically, for Sacks in which to dispose of their garden waste. The fact that the marginal cost of these collections is not zero tends to constrain the quantities delivered. It may also have the effect of making householders feel comfortable with that service, though equally, there are situations in which households are put off using the service because material which they had thought was being collected for composting is actually being collected along with refuse for disposal to landfill.

It is the intention is to maintain a collection for garden waste, one option is to maintain the existing approach and following exactly the same procedure as for **Issues 1**. This enables control to be maintained on the delivery of garden waste, whilst also enabling capture of the critical kitchen waste element from the waste stream.

If the intention is to combine the collection of kitchen waste would garden waste, then clearly, in order to do this effectively, one cannot really impose a charge for this collection system. This would mean that the garden waste collection which was previously offered only at a cost would certainly be made available, implicitly, free of charge. In this situation, the problem of waste growth arises. For this reason, we would recommend that the approach taken is to maintain the existing pay per sack garden waste collection alongside dedicated collection of kitchen wastes.

Issues 3:
In this case, the pre-existing system inserts no control over the delivery of garden waste into the refuse collection system. Furthermore, the collection occurs using wheeled bins, and the collection service allows for the collection of unlimited side waste. This is the situation which is most likely to approximate to one in which a significant quantity of garden waste is already to be found within the refuse collection. Arguably, this system is already indifferent to the quantity of waste collected, and the introduction of a free, separate collection of garden waste might not be expected to have the same effect on waste arisings as in the case where the delivery of garden waste into the refuse collection is seriously constrained.

One approach, therefore, would be to introduce alternating collections of kitchen garden waste and refuse. This type of system tends to experience difficulties in capturing kitchen wastes as effectively precisely because the odorous nature of the material makes it tempting to deposit kitchen waste in whichever container is likely to be collected the following week. However, tools which make the collection of kitchen waste comfortable for the householder can at least improve the prospects for capturing this material.

From the perspective of treatment of the material collected, the seasonality of the waste arising can be of concern. It is not only the seasonality of the quantity, but also the seasonality of the mix, which may be problematic. Furthermore, now that in vessel systems are required to treat all material containing kitchen wastes, the fact that the quantity of material will be vastly increased by the accompanying garden waste implies that the overall cost of treatment for this material can be significant.

In this type of situation, it would be reasonable to expect some reduction in the delivery of garden waste to civic amenity sites. The convenience of the garden waste collection may also act as a disincentive to engage in home composting. Systems to promote home composting therefore face something of an uphill struggle in seeking to convince householders of the merits of dealing with material at home when at the same time they are being encouraged to separate out the material for delivery into a kerbside collection system.

Issues 4
In these cases, where there is no formal constraint on garden waste entering refuse, but where some form of volume constraint exists, one finds oneself, arguably, in a situation straddling 'Issues 1' and 'Issues 3'. In order to deliver 'Issues 1', it would probably be important to offer strong 'back-up' solutions for garden waste, especially where refuse continues to be collected in wheeled bins. Where the wheeled bin approach (collecting garden and kitchen waste) is chosen, it seems likely that there would be an increase in waste arisings, though less so than in the 'Issues 3' case. Evidently, in more urban areas, one would favour the Issues 1 approach, based around kitchen waste collections.

Enforcement and Refuse Containment

In al the cases above, it is preferable, from the perspective of cost optimization, to reduce refuse collection frequencies. This raises questions about containment of the residual waste. For example, on sack-based schemes, the concept of dropping to fortnightly collections may seem unpalatable.

Possible ways round this might be the use of non-wheeled bins, with sacks used to contain refuse within these. This enables more efficient sack based collection to remain in place, whilst respecting the wishes of people to contain refuse. It should be recognized that where weekly collections for kitchen waste are in place, there is at least an improved possibility to ensure that sacks do not have a high putrescible content.

In biowaste collections, the purity of capture is an important consideration. In some garden waste schemes, contamination often occurs through the sweeping of garden paths, and addition of non-biodegradable wastes from gardening activities. In the case of kitchen wastes, contaminants include plastics (especially 'wrong bags' where biobags are being used) and other materials. This raises the issue of how to enforce purity of capture. Where materials are collected in wheeled bins, this is not straightforward, and only visual (surface) inspections can take place (of both refuse and residuals). In food waste collections using biobags and small buckets, there are greater possibilities for closer inspection of the whole. Sack-based collections for refuse may also offer better possibilities to seek to control garden waste deliveries.

Enforcement has implications for downstream pre-treatment at biowaste treatment plants (composters and digesters). At high purities, compost plants may not need sophisticated pre-segregation equipment. Digesters may not have so many problems with plastics, removal of which also implies loss of volatile solids from the plant (and increased disposal costs). Clearly, it is desirable to avoid both.

In all of the cases discussed above, consideration has to be given to the size of the receptacles taking into account:

1. Variation across households;

2. The frequency of the collection; and

3. The expected delivery of the material being collected, considered in the context of the 'pressure' one seeks to put on households. In the management of biowaste, this is as important for the biowaste container as it is for the residual waste container.

The latter is to some extent a substitute for the inability to charge households directly (so incentivising them to 'do the right thing').

12.1.2 Systems for the Collection of Food Waste

Running source separation for food waste, both at households and big producers, implies the need to find tools to confront problems linked to the specific features of the material: *its fermentable nature and its high moisture content.* In this respect, where households are provided with tools to avoid nuisance, convenience will result in an enhanced participation and will thus determine higher collection quantity/quality.

These issues have to be best tackled through:

- a relatively intensive collection schedule;

- the use, in most cases, of collection systems at kerbside so as to enhance the participation rate and ensure purity of collected material; and

- the use of watertight, transparent tools to hold the waste ("Biobags").

The use of the bags:

- Prevents pest attraction (insects) and production of leachate and keeps the bins as clean as possible. This, in turn, makes it possible to cut down the frequency of washing. In many cases where such bags are being adopted, bins are considered as personal equipment and are washed by households themselves once to twice a year. Otherwise, a much lower number of washing rounds needs to be provided by the public cleansing service (e.g. only in summertime) as compared to traditional schemes (where washing had to be usually performed at each pick-up);

- Avoids nuisance generally related to delivery of 'loose' material inside the bin, and makes it possible to collect even meat and fish scraps along with vegetables and fruit residues;

- Increases therefore overall captures of food scraps that, in turn, allow a significant reduction in the collection frequency for residual waste;

- Prevents, because of their small size, the delivery of bulky materials (e.g. bottles, cans), allowing higher biowaste purity.

The bag is to be placed as a liner inside a small fit-for-purpose caddy for households. Once full, bags have to be filled inside:

- buckets - in areas with detached houses and gardens so as to reduce the pick-up time for each dwelling (loading is manual) and prevent households from delivering garden waste inside the bins

- or in a larger bin whose capacity usually ranges from 80 to 240 litres for 10 to 20 families depending on the collection frequency. This system is used for flats in high-rise buildings.

A specific collection round with a higher frequency may be planned and run in resort places where density of restaurants and canteens justifies such a scheme.

As to the most sparsely populated settlements (rural areas) food waste should not be source-separated because, on the one hand, an intensive scheme would be too costly, and on the other hand, in such situations promotion of home composting proves to be much more effective, and this cuts further the need to target food waste.

An option in smaller settlements is much more localized collection of materials with delivery to community composting facilities. These can be positive mechanisms for encouraging community participation (and can be integrated with cultivation activities, and community cafes and the like).

Bags may be biodegradable, or not (transparent polyethylene bags). The latter is cheaper, but leads to a considerable increase in costs for the equipment (bag openers and wind screens) and for the disposal of rejects, inasmuch as such equipment implies a higher percentage of compostable / composted materials being discarded inside the rejects. Some detailed assessments have recently led to the preference for the use of biodegradable bags instead of the combined system of polyethylene bags with additional pre-treatment equipment.

12.2 System Costs – Putting it All Together

Eunomia has recently been modelling collection systems in many different local authorities. In addition, we have led a survey of collection costs across the whole of Europe, and have based the development of our model on the innovative systems for kitchen waste collection described above.

An indication of the impact of introducing such collection systems can be gained from the following. In the three figures below, we illustrate, for an English Local Authority, the costs of systems where four different collection systems operate. These are:

1. Refuse collection only.
2. Dry Recyclables Only (weekly, on vehicle sort).
3. Weekly Dry Recyclables, Weekly Kitchen Wastes, Fortnightly Refuse.
4. Weekly Dry Recyclables, Fortnightly Kitchen and Garden Wastes and Fortnightly Refuse.

In each figure, cases where captures of the separately collected materials are high and low are modelled (the different coloured bars).

The successive figures show what happens to the relative costs per household of the different systems as disposal costs increase. There are a number of points of interest:

- Firstly, in all figures, it is clear that as long as refuse collection drops to a fortnightly basis, the principal reason for the costs of separate collection being higher relates to the dry recyclables collection. Focussing on Figure 28, even at low disposal costs, it can be seen that the introduction of a weekly kitchen waste collection on top of the recyclables collection hardly changes the costs of the overall system. Typically, reducing refuse collections to a fortnightly round causes the per household costs to fall to around two-thirds of their level for weekly collections. Similarly, if alternating fortnightly collections of kitchen and garden waste and refuse replace the weekly refuse collection, the effect on system costs is small. However, in the modelling, the potential increase in waste collected has not been accounted for. In some UK garden waste collections, deliveries of garden waste already stand at around 350kg per household. Whilst this can be useful in increasing recycling rates, to the extent that it represents material which did not have to be collected, it is an expensive system;

- When disposal costs are low, the low capture systems are, in the round, cheaper than the high capture ones. As the disposal costs rise, the situation reverses. This is entirely logical. If more of the material is collected as refuse, then the lower the costs of disposal of refuse, the lower will be the system costs. As disposal costs increase, the high capture systems begin to look cheaper. This, again, is as one would expect. However, there are some important caveats here. Much depends on what is the cost of treating the biowaste which is collected. In the figures shown, the assumption is that all the material is sent to a compost plant. We carry out a separate analysis below to elaborate the sensitivities to the treatment costs (relative to the disposal cost);

- As disposal costs rise, the costs of high capture recycling and composting systems become cost competitive with a system which simply collects refuse and dumps it in a landfill. Our 'rule of thumb' estimate is that non-landfill residual waste treatments are likely to cost local authorities in Northern Ireland around £60 per tonne. Possible exceptions to this rule of thumb would arise, in theory, where large incinerators were installed. This seems unlikely to happen in Northern Ireland, with Belfast being the only location where this would seem appropriate, if indeed it was deemed desirable. Hence, for the most part, the alternatives to landfill – which must be found in Northern Ireland – are likely to be more, not less, expensive than the landfill option considered in the Figures. As such, subject to considerations around the costs of biowaste treatments (see below), the argument in favour of source separation of biowastes on cost grounds alone may increase over time as a) landfill costs rise, and b) the 'background' disposal cost is seen no longer as landfill, but non-landfill treatments (because of the Landfill Directive and the Landfill Allowance Trading Scheme).

The above analysis merely illustrates what has already happened in Austria, Germany, Belgium, the Netherlands, and increasingly, Italy, Spain and even some of the Candidate countries such as the Czech Republic. As disposal costs rise, the logic of separate collection of biowastes becomes quite compelling. Generally, in the countries mentioned, separate collection of biowastes ***saves money***.

The clear lessons are that in future:

- All systems will cost more than they do today; and
- The increase in disposal costs makes separate collection systems more attractive from a cost perspective.

Increasingly, as disposal costs rise, high capture separate collection systems will become cost competitive. In this context, given all the policy risks associated with 'not recycling' (there is no legislation on the horizon asking municipalities to 'stop recycling'), the logical strategy is to seek to develop high capture systems in the years ahead. As important (from the perspective of costs and environmental impacts) is the fact that constraining arisings becomes ever more important as the costs of dealing with waste in *any* way increase.

Figure 28: Per Household System Costs at £15 Landfill Tax

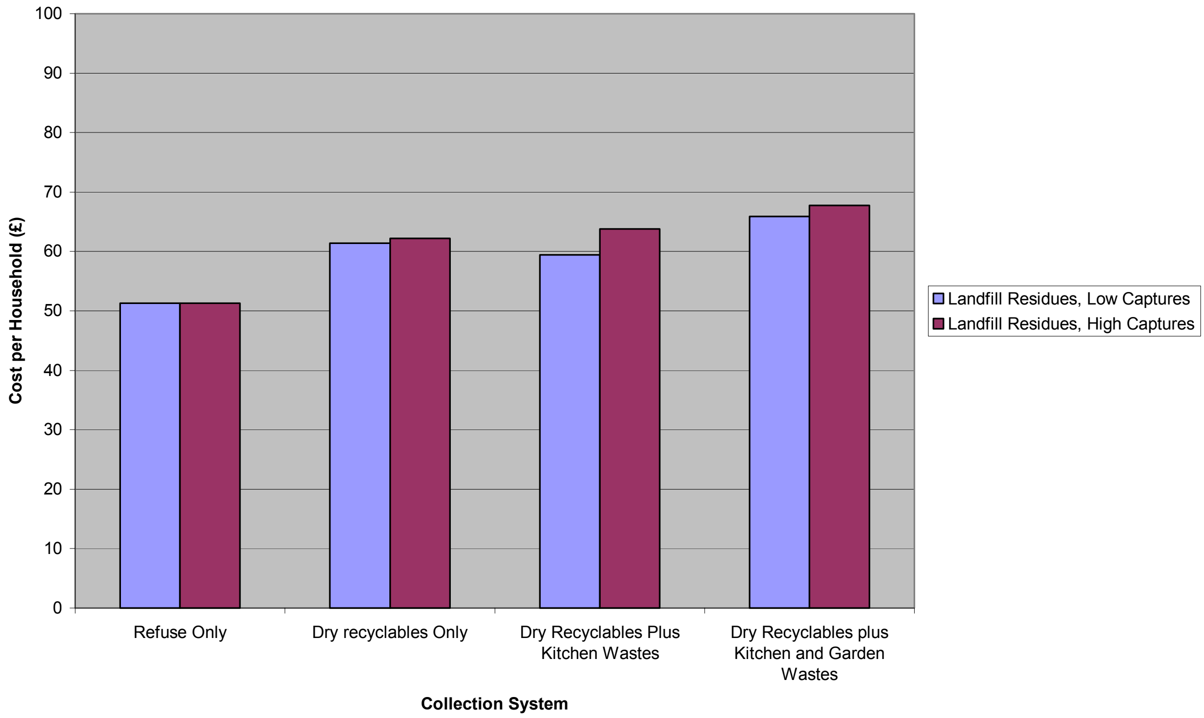


Figure 29: Per Household System Costs at £25 Landfill Tax

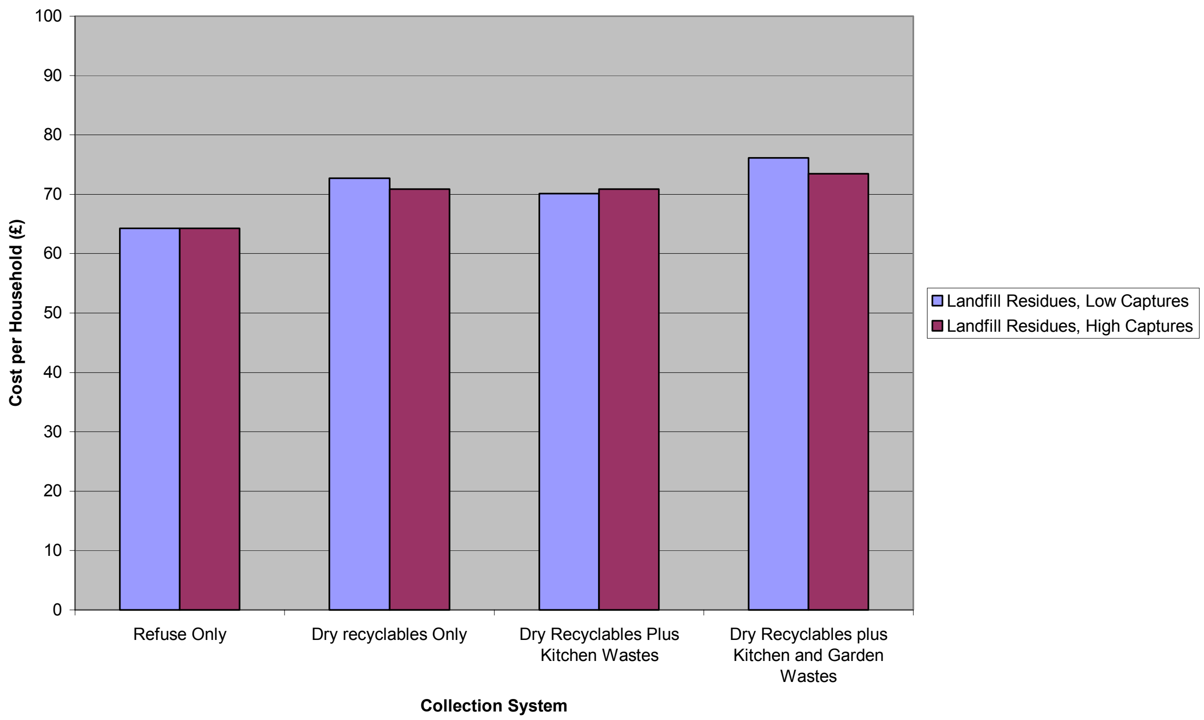
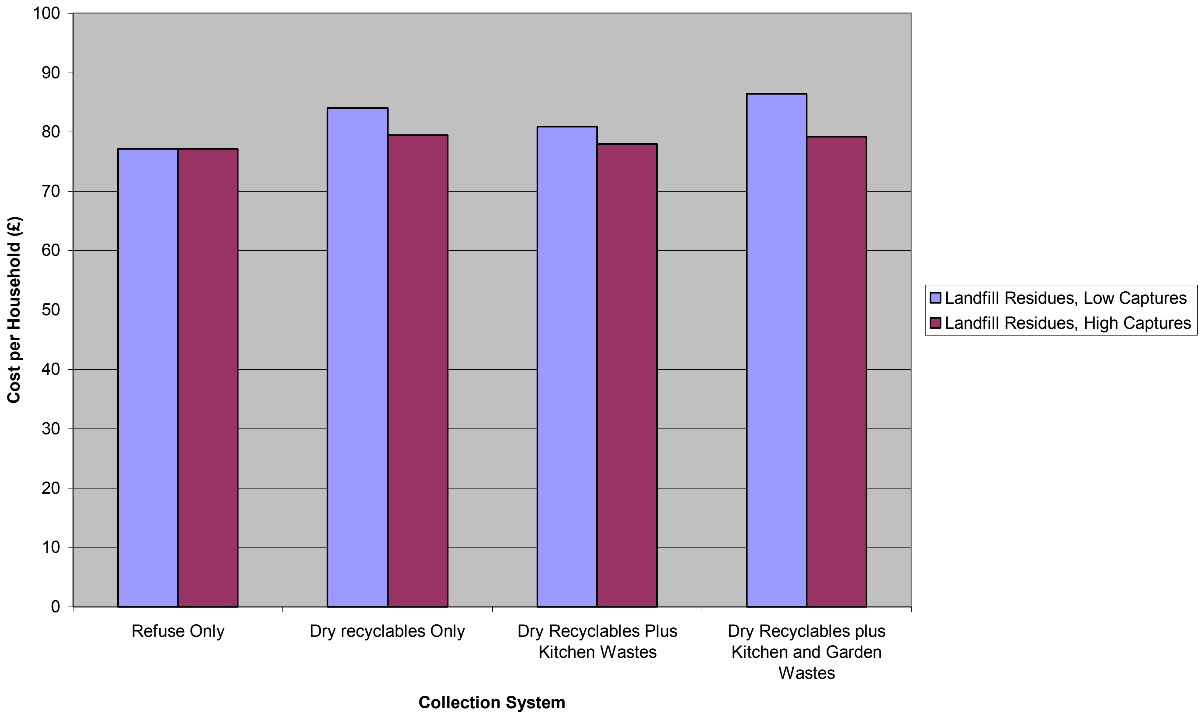


Figure 30: Per Household System Costs at £35 Landfill Tax



12.3 AD or Compost? What is the Optimum Treatment Situation for Biowastes?

In the previous Chapter, we looked at whether the payback periods for the investment in digesters were acceptably short at gate fees of £35, £45 and £55 per tonne. We have carried out work for the Composting Association in the context of the discussions regarding the UK ABPR and the effects of the various requirements are likely to push up the costs of in-vessel composting to £35 per tonne or so for smaller facilities. This is lower than most digestion plants are likely to be able to compete with. At first glance, if it costs £55 to digest material that could otherwise be composted, why would one spend additional money on digestion?

There are a number of responses one can offer:

a. digestion might be justifiable at a lower gate fee (of the order £40 per tonne). However, it still seems likely that aerobic systems would be less expensive;

b. there are greater environmental benefits associated with digestion;

c. in more built-up areas, the contained nature of digestion offers specific advantages in terms of odour minimization;

d. the land take is less, and again, this may be important in urban areas;

e. possibilities for grid support are offered by AD plants;

f. digestion contributes to renewable energy targets; and

g. digestion offers interesting possibilities for treating former foodstuffs alongside organic fractions of municipal waste.

But perhaps more interesting still is the fact that whilst unit costs of digestion may be higher, system costs can be maintained at a low level by keeping kitchen and garden waste collections separate.

In Table 31 below, we show plausible scenarios (based on UK and international experience) that might flow from implementing a) kerbside collection systems of kitchen waste only and b) kerbside collections of kitchen and garden waste. We have estimated elsewhere that the latter system can lead to collection of an additional 100kg per household, possibly more in suburban areas. The capture of garden waste in such systems tends to be rather better than that of kitchen waste.

The Table shows that even if the costs of digestion and the costs of composting differ by £20 per tonne, by keeping the kitchen waste collection separate and digesting that material, it is possible to operate a treatment system at lower cost than the system running on a mixed kitchen and garden waste collection. This is because in the former system, garden waste collected at CA sites can be treated through windrow composting, which is the lowest cost form of treatment. In the kitchen and garden waste collection, all material has to be treated in-vessel. Since the treatment costs cannot be differentiated, and since much greater quantities of garden waste are likely to be collected in this system, only a relatively small amount of biowaste (the garden waste which was not collected at the doorstep) is sent to the lowest cost treatment (the open air windrow). Hence, as the final row shows, a system which treats kitchen waste through digestion and garden waste through windrows can be cost competitive with one where kitchen and garden waste are collected together for composting in-vessel.

Table 31: Economics of Two Biowaste Collection and Treatment Systems

		Kitchen Waste Only		**Kitchen and Garden Waste**	
		Available (per hhld)	**Captured (per hhld)**	**Available (per hhld)**	**Captured (per hhld)**
Kerbside	Garden Waste	70	20	250	250
	Kitchen Waste	200	140	200	70
CA Site		150	150	50	50
			310		370
	Unit Cost Open-air Windrow		**£19.00**		**£19.00**
	Unit Cost In-vessel Compost				**£35.00**
	Unit Cost Digestion		**£55.00**		
Treatment Costs (£ per hhld per year)					
	All to digestion		£8.80		£11.20
	HWRC site to Open-air		£2.85		£0.95
	HWRC Site to In-vessel				£1.75
Totals	HWRC site to Open-air		£11.65		£12.15
	HWRC to In-vessel				£12.95

This example has used plausible numbers, and has deliberately kept the cost margin between digestion and composting at a relatively high level. Of course, if this differential is reduced, the integrated system of separately collected kitchen waste alongside AD of the material becomes even cheaper relative to the system in which garden waste and kitchen waste are co-collected.

12.4 Summary

The importance of biowaste collection and management systems is increasingly well understood. Innovative systems are now available for implementation which:

- maintain costs at low levels; and
- ensure that there is no undue increase in collected waste through offering free garden waste collections to households.

We have sought to illustrate how:

a) by considering the collection system as a system, and notably, by considering the integration of biowaste and refuse collections, the costs of separate collection can be kept close to those of existing collection systems;

b) by aiming for high captures through separate collection, because the options for residual waste management are becoming more expensive, the costs of separate collection systems can be kept below what they will otherwise be if the system simply revolves around refuse collection and disposal;

c) by keeping the garden and kitchen waste collections separate, not only is the collection system cost-optimised, but so is the treatment of the biowastes; and

d) last but not least, even where one takes the view that there remains a cost differential between composting and AD, AD can be part of a system which is cheaper than some involving separate collection of kitchen and garden waste for composting only.

These conclusions are of significance. They point the way towards truly integrated waste management. AD has a role to play in sustainable systems of this nature. It is to the environmental issues that we now turn.

13.0 ENVIRONMENTAL IMPACTS OF AD SYSTEMS

The environmental impacts of AD systems based around the source separation of municipal biowastes have been the subject of relatively few studies until quite recently. Seven studies stand out as having attempted to understand these impacts in comparison to other waste management options. These are:

- A study for the European Commission on the costs and benefits of different approaches to managing biodegradable municipal waste;[58]
- A study for the European Commission on the greenhouse gas emissions from different waste management options;[59]
- Life cycle studies by Edelmann and Schleiss,[60] Vogt et al,[61] de Groot and van Lierop[62], and Sundquist;
- Life-cycle and cost-benefit studies carried out on behalf of the Danish EPA.[63]

All of these studies support a ranking, on environmental grounds, of AD above composting. Extracts from the reports are given below.

13.1 Vogt et al

In Figure 31 the results of the comparative evaluation between four systems examined is shown. The systems are:

a. A wet digestion system - The chosen technique for all the here is a one-stage, mesophilic, wet fermentation. Products are biogas that is used in a gasmotor and fermentation residue. 50% of the fermentation residue is used directly in agriculture as fertilizer while the remaining share is composted with mature compost as product; and

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[58] D. Hogg et al (2002) *Economic Assessment of Options for Dealing with Biodegradable Waste*, Report to DG Environment, European Commission, by Eunomia, Scuola Agraria del Parco di Monza, HDRA Consultants, ZREU and LDK.

[59] Smith, A., K. Brown, S. Ogilvie, K. Rushton and J. Bates (2001) *Waste Management Options and Climate Change*, Final Report to the European Commission, DG Environment, July 2001

[60] Werner Edelmann and Konrad Schleiss (1999) *Ecologic, Energetic and Economic Comparison of Treating Biogenic Wastes by Digesting, Composting or Incinerating*, Paper written for R99, Geneva, Switzerland.

[61] Regine Vogt, Florian Knappe and Andreas Detzel (2001) *Environmental Evaluation of Systems for the Recovery of Biogenic Waste*, Proceedings from the ORBIT 2001 Conference.

[62] de Groot, Mark and Wim van Lierop (1999) Environmental Efficiency of Composting versus Anaerobic Digestion of Separately Collected Organic Waste, *Proceedings from the ORBIT 1999 Conference*, pp.667-676.

[63] Danish EPA (2003): *Skal husholdningernes madaffald brændes eller genanvendes? Samfundsøkonomisk analyse af øget genanvendelse af organisk dagrenovation* [Is the food waste from the households to be incinerated or recycled? A welfare-economic analysis of increased recycling of organic household waste.] Environmental project no. 814. www.mst.dk/udgiv/publikationer/2003/87-7972-685-2/html/.

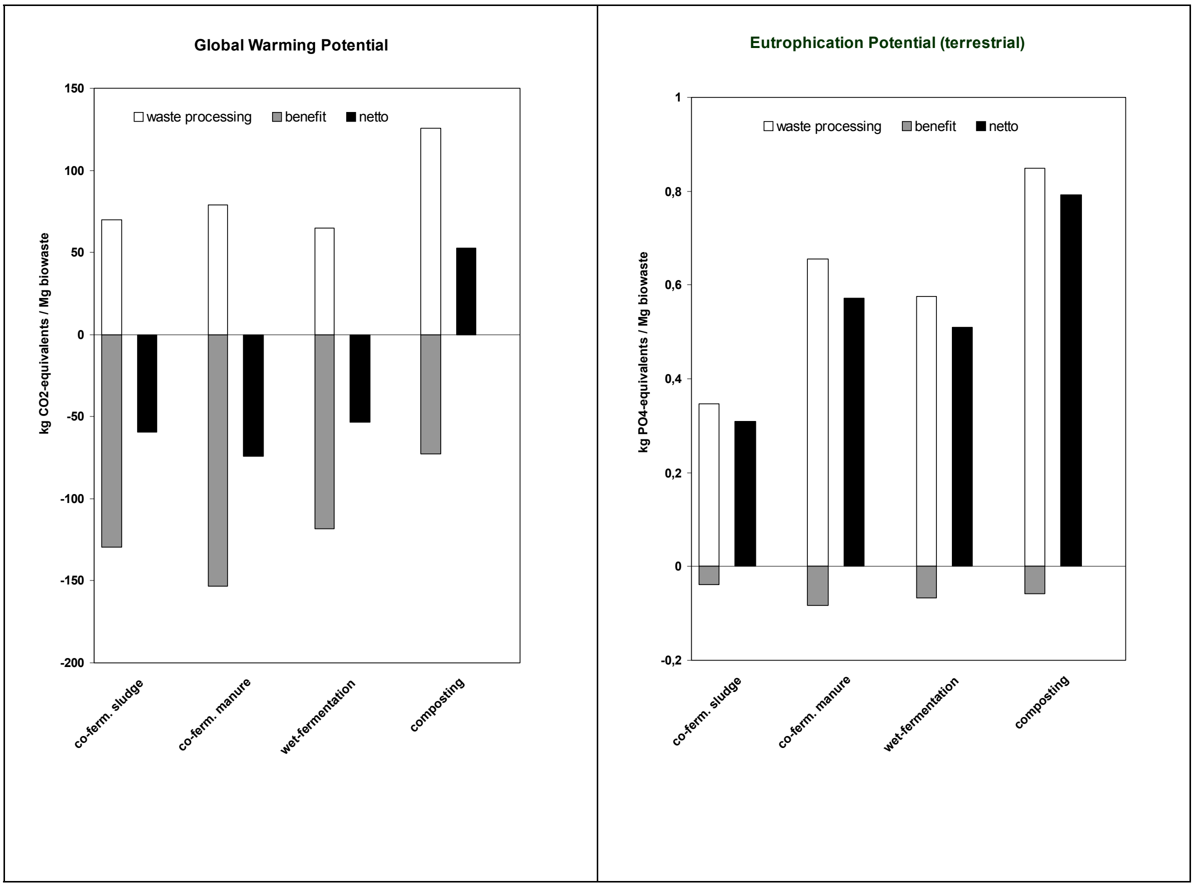
b. A system of co-digestion with manure - The technology is similar to that of wet fermentation. The residue is not dewatered but used completely and directly in agriculture on nearby farm land;

c. A system of co-digestion with sewage sludge - The technology is similar to that of wet fermentation. The produced sludge is dewatered and then used in various applications (50% incineration, 28% agriculture and 22% recultivation); and

d. Composting - This model consists of container composting in the intensive-/main stage, while the after-composting stage takes place in an open, simple roofed windrow. The product is mature compost.

It is clear that the utilization or products and the corresponding substitution benefits can be of great importance. Thus, the results for the global warming potential and the input of heavy metals in soils depend mainly on the substitution effects.

Figure 31: Results of the Ecological Valuation, Global Warming and Eutrophication



The waste management systems with fermentation processes as the main treatment register benefits ('netto') in the impact category global warming potential. The substitution effects are much higher than the direct effects resulting from the treatment processes alone. There are advantages to the co-fermentation with slurry, and the management systems with composting units are evidently worse. The study suggests composting processes are dominated by emissions of methane and nitrous oxide, which are responsible for nearly 50% of the negative effects. This is controversial in this study, since the question of methane emissions from compost remains poorly characterized. In the study, benefits resulting from the substitution of peat do not outweigh the direct harmful effects.

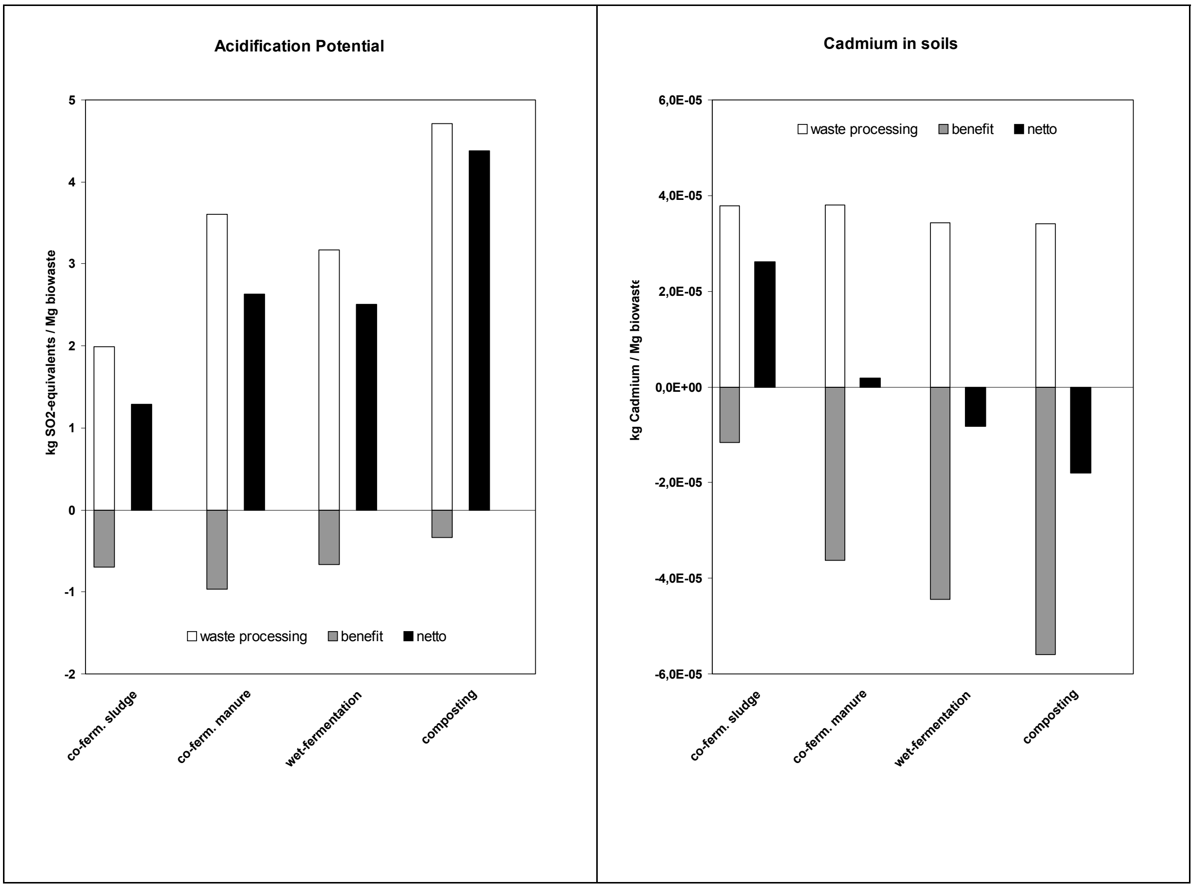
The negative effects of the management systems with fermentation processes mainly result from the emissions of nitrous oxides caused from the application on farm land. Due to the fact that there is no loss of nitrogen during the treatment process itself, the emissions resulting from the application of slurry are the highest. In spite of this, co-fermentation with slurry generates significant substitution effects. These assume the nitrogen content replaces an equivalent amount of artifical nitrogen fertilizer and the associated ecological impacts. Nevertheless, the main substitution effects (80%) result from the generation of electricity.

The results for the terrestrial eutrophication potential are different. The substitution effects are very small compared with the direct harmful ones. The emissions of ammonia from the application of the residues or those occuring during open composting processes are dominant. The assumption that half of the residues from co-fermentation with sewage sludge are incinerated are the reason why this option fares relatively well.

No one of the alternatives for the recycling of biowaste from households shows benefits (‘netto’) in the case of the acidification potential. Management systems with composting units are associated with the highest negative effects. The recycling route including co-fermentation with sewage sludge presents the best results. The options with fermentation processes show small differences across their results.

Here, like for the eutrophication potential, the emissions of ammonia from the application of the residues or those occuring during open composting processes are predominating. Main parts of the nitrogen content of biogenic waste are getting available for gaseous emissions resulting from the biodegradation. On grounds of disposing the residues from co-fermentation with sewage sludge to 50% by incineration, that kind of waste utilization is combined with the lowest ecological harmful effects. The fact that the substitution effects are also smaller than those of the other options with fermentation processes does not matter in this case.

Figure 32: Results of the Ecological Valuation, Acidification and Cadmium in Soils



Linked with the application of the residues on farm land or for recultivation measures there is a loading of heavy metals and other harmful substances in soils. In most of the cases the results (netto) for that impact category depend on the content of the relevant substances in the biogenic waste itself. The less the loss during the process of waste treatment, and the more residues are applied in open field utilisations, the higher are the negative results in this impact category.

There is just one exception. Artificial fertilizers have a remarkable loading of cadmium. Relating to the content of nitrogen and especially phosphate, that loading is as high as that of the residues of the biowaste treatment. The same occurs in the substitution of bark humus. Relative to the content of organic matter, the loading of cadmium is much higher than that of the residues from biowaste treatment. Due to these facts, the substitution effects in using the residues from composting processes lead to the highest benefits. As for the option of co-fermentation with sewage sludge, the substitution effects are the least. Only half of the residues from this recycling route substitute fertilizer, the rest is incinerated and not combined with any substitution effects in this impact category.

On the other hand the direct effects are still as high as for the other investigated options. This does not only derive from the content of heavy metals in the biowaste, but also depends on the applied method of dewatering. In waste water treatment plants in Germany about 20% of the used auxiliary agents to dewater sewage sludge are ferrous salts. However, these ferrous salts are contaminated with heavy metals which accumulate in the dewatered sewage sludge and increase the load of cadmium when applied in the open field.

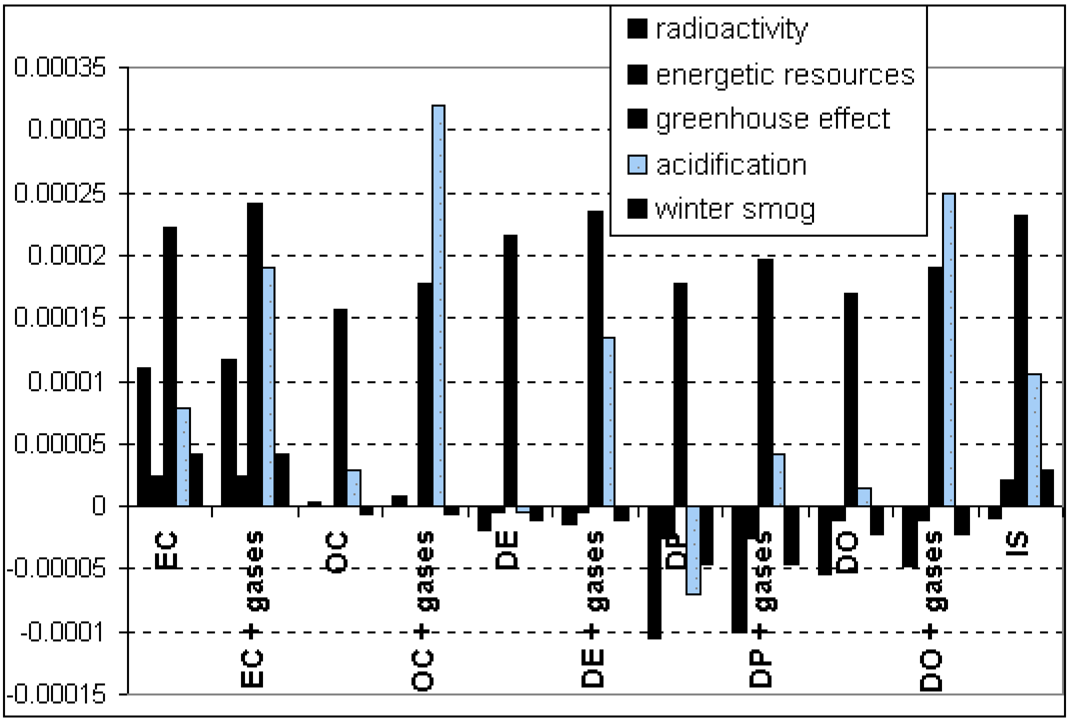
13.2 Edelmann and Schleiss

This study examined a number of systems:

- EC: fully Enclosed and automated Composting plant with waste air treatment in a biofilter: The data were derived from a fully enclosed channel composting plant (IPS) with a compost biofilter;
- OC: Open Composting in boxes covered by a roof and in open windrows: Compaq-Boxes protected against rainfall followed by composting in open, low windrows reversed frequently and covered by gas permeable textile sheets;
- DP: fully enclosed thermophilic one step plug flow Digestion (horizontal Kompogas-digester) with aerobic Post-treatment in an enclosed building equipped with compost biofilters;
- DE: combination of thermophilc Digestion combined with fully Enclosed, automated composting in boxes (BRV-technology), where 40% of the raw material was digested before the addition to the compost line. The air is cleaned by bio-washers;
- DO: combination of multiple stage, thermophilic batch Digestion (romOpur-technology) combined with Open windrow composting where 60% of the raw material was digested before the addition to the compost line; and
- IS: Incineration in a modern incineration plant including Scrubbing of the exhaust gas streams.

Key results are shown in Figure 33 and Figure 34. The lower the values, the smaller is the impact. Negative values correspond to a benefit. For the nitrogen and phosphorus present in the compost, benefits corresponding to the savings of artifical fertilizer production were taken into account. In the incineration plant (IS) the nutrients are lost.

Figure 33: Ecoindicator 95+ -points for the impact categories radioactivity, energetic resources, greenhouse effect, acidification and winter smog. The data "+gases" of the biotechnological processes were calculated including emission data (taken from literature) for NH_3, N_2O and H_2S into the air. NH_3 -emissions are reduced to a large extent by the biofilters of the fully enclosed plants (EC, DP and DE).



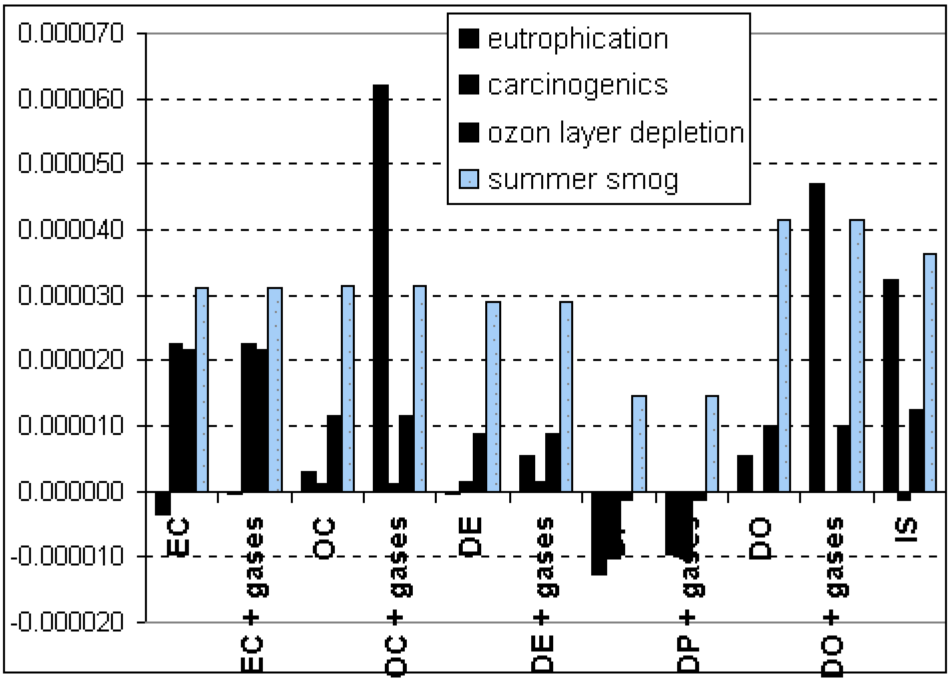
The authors conclusions include the following:

The ecological and the economic comparisons […] show that the biotechnological treatments for biogenic waste treatment are generally favorable to incineration. The pure composting technologies (EC and OC) appear to be less ecological than digestion.

The three categories greenhouse effect, acidification and heavy metals play an important role in the ecobalance. The greenhouse effect is caused mainly by CO_2 and CH_4. CO_2 emission cannot be prevented if biogenic matter is degraded. The CH_4 emissions count 21 times more than CO_2. It is not surprising that a considerable amount of methane is emitted while composting […] A large improvement potential exists especially for the composting part in digestion plants i.) by obtaining after digestion aerobic conditions as quickly as possible and ii.) by eventually improving the biofilter performance.

Heavy metals have a very strong effect in UBP and also in Ecoindicator 95, provided that there exists an export into the water. Heavy metals are deposited by rain and air on the biomass which afterwards is treated in a processing plant. The treatment itself does not attribute significantly to the heavy metal load of the biomass (metal deriving from chopping and from transporting engines etc.). Because the heavy metals are supposed to be in a more or less inert form bound in the ashes of the dump, IS shows an advantage: in this case the heavy metals are withdrawn from ecological cycles. Considering the fact that the heavy metal load of the compost usually is far below the legal limits, it does not seem logical yet to burn the (precious) organic substance in order to reduce heavy metals present in air and rain.

Figure 34: Ecoindicator 95+ -points for the impact categories eutrophication, carcinogens, ozon layer depletion and summer smog. The data "+gases" of the biotechnological processes were calculated including emission data (taken from literature) for NH3, N2O and H2S into the air.



When comparing the different technologies, energy plays a predominant role. Digestion plants are better from an ecological point of view, because they don't need external fossil and electrical energy. If only one quarter of the biogenic waste is digested, a plant can be self sufficient in energy. The production of renewable energy has positive consequences on nearly all impact categories, because of saving of or compensation for nuclear and fossil energy. This reduces the impacts of parameters such as radioactivity, dust, SO_2, CO, NOx, greenhouse gases, ozon depletion, acidification or carcinogenic substances. Digestion plants could show an even better ecobalance, if they were constructed near an industry which can use the waste heat of electricity production all year round.

It is nearly impossible to take advantage of waste heat while composting. Looking at the results of the ecobalance and the economic situation, it is difficult to understand that today composting plants are constructed, where high value fossil and nuclear energy is invested to destroy the renewable solar energy, which is fixed in the chemical compounds of biomass and thus in the biogenic waste.

The emphasis is on the energy-related benefits of digestion. Again, some may consider the analysis of emissions from composting as controversial. However, in this study, some attempt was made to measure the actual emissions of carbon dioxide rather than to base these on reference to estimates in life-cycle literature.

13.3 Summary

Most studies follow the pattern above. For biowastes, digestion is an environmentally superior option to composting. There are debates as to whether AD is superior to incineration, at least where incineration operates to high standards. Some studies have argued that AD is not unequivocally superior to conventional incineration. These studies tend to be either:

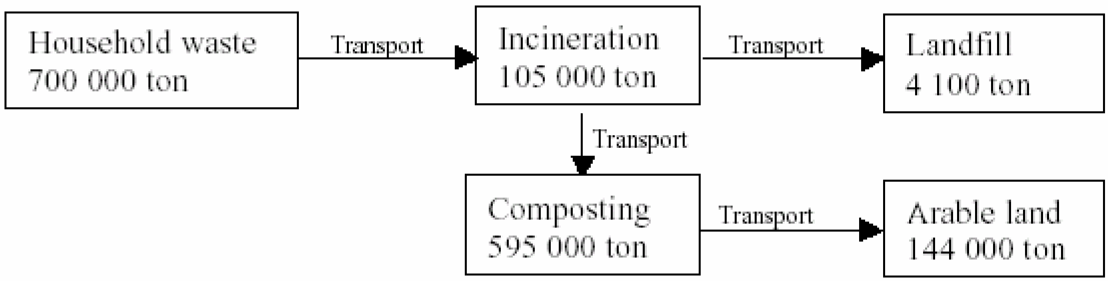
a) life cycle studies where the issues of collection logistics, and environmental benefits from composting are poorly characterized; or

b) Nordic studies which compound the errors just mentioned by assuming low unit costs for incineration.

By way of example, a recent study in Denmark suggested that it was better to incinerate food waste than to compost or digest it.[64] The study's conclusions rest much more heavily on the assumptions concerning the approach to collecting food waste than to any positive effects of the incineration process.

The system modelled in the study – based on optical sorting of bags – is a poor approach for cost optimization (though it may not be without uses in specific circumstances). Biowaste collections have a crucial role to play here in enabling a reduction in the frequency of refuse collections. Furthermore, the reject rates reported in the EPA study – 30% at the digestion plant and 15% at the compost plant - are enough to make one realise that such an approach could hardly be considered the best one in the circumstances. Lastly, in the separate collection system, the materials were assumed to be first all taken to an incinerator (even though the materials are destined for a biowaste plant – see Figure 35 below). There, they are screened for contraries before being moved on to a biowaste facility.

Figure 35: Collection Logistics as Modelled in Danish EPA Study



For these reasons, mainly concerning the researchers inability to understand what constitutes sensible logistics, the comparison made in the study is rather like having a race between two athletes, one of whom has both legs broken at the start!

The Danish study did not look at the impacts of displacing fertiliser use / peat and reducing greenhouse gas emissions. Where cost-optimized collection systems are deployed, composting and digestion systems are likely to fare well in more comprehensive cost benefit analyses. Furthermore, other studies by Hogg et al[65] and Smith et al[66] suggest that the greenhouse gas fluxes are positive in favour of biowaste treatments, especially if the time dimension of these emissions is considered. Cost benefit studies, such as those of Hogg et al, and a forthcoming Australian study, also highlight significant economic benefits associated with compost utilisation.[67]

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[64] Danish EPA (2003): *Skal husholdningernes madaffald brændes eller genanvendes? Samfundsøkonomisk analyse af øget genanvendelse af organisk dagrenovation* [Is the food waste from the households to be incinerated or recycled? A welfare-economic analysis of increased recycling of organic household waste.] Environmental project no. 814. www.mst.dk/udgiv/publikationer/2003/87-7972-685-2/html/;

[65] D. Hogg et al (2002) *Economic Assessment of Options for Dealing with Biodegradable Waste*, Report to DG Environment, European Commission, by Eunomia, Scuola Agraria del Parco di Monza, HDRA Consultants, ZREU and LDK.

[66] Smith, A., K. Brown, S. Ogilvie, K. Rushton and J. Bates (2001) *Waste Management Options and Climate Change*, Final Report to the European Commission, DG Environment, July 2001

[67] D. Hogg et al (2002) *Economic Assessment of Options for Dealing with Biodegradable Waste*, Report to DG Environment, European Commission, by Eunomia, Scuola Agraria del Parco di Monza, HDRA Consultants, ZREU and LDK; Nolan ITU (2004, forthcoming) *TBL Assessment of Garden Organics Management*, Final report to the NSW Dept of Environment and Conservation Sustainability Programmes Division.

It is always difficult to make unequivocal statements as to the superiority of one or other option given the need to understand trade-offs across impacts on different media. However, there are strong suggestions that AD provides one of the best, if not the best, approach to managing biowastes from an environmental perspective.

In the past, issues of cost (relative to composting) has made this a difficult option to recommend. Now, notably in the UK, the costs of composting are increasing. Equally, new and innovative approaches to waste collection makes it possible, as we have seen, to integrate AD into a sustainable system of logistics and treatment for biowastes. Hence, the potential for, and rationale for, making use of AD in the treatment of municipal biowastes, especially where co-digested with other materials, is perhaps as strong as it ever has been.

14.0 ISSUES PERTAINING TO PLANT LOCATION

In the context of what might be considered, hypothetically, as a regional strategy for AD, some consideration needs to be given to locational issues. Issues associated with, for example, the costs of grid connections, as well as opportunities associated with off-grid provision, are clearly of potential significance.

14.1 Site Size and Land Requirement

Clearly, one issue for inclusion in any screening process is the site area. Evidently, this in turn depends upon the capacity of the facility.

Typically, in Northern Ireland, if only biowastes were being considered, we would not expect large sites. This relates to the relatively dispersed population, and the desirability of marketing end products close to the site of their production. For a 100,000 person (approx. 40,000 household) catchment, a 10,000 tonne facility would probably be adequate. This would require a land area of the order 0.24-0.3 hectares.

Co-digestion opens up the potential for:

- Scale economies;
- Better capacity utilisation;
- Improved quality of end-products; and
- More stable energy generation.

Furthermore, there may be a strong rationale for offering industries needing to treat former foodstuffs with a viable option. This could be either composting, or AD. But it may well be that for Category 3 material, AD provides a more viable option. This would also improve the collection logistics, whilst also lowering the unit costs for the facility itself.

14.2 Grid Connection

Certain technical and financial aspects of AD facility development are site dependent. In particular, the technical requirements and costs of energy transmission depend in part upon the location of the AD facility relative to the energy supply network and / or end-user.

Generally, NIE needs to consider a large number of issues when connecting generators to the grid, such as safety, voltage rise, fault levels and maintaining the quality of electricity supplies to others, to name but a few. NIE assesses all applications on a step-by-step connection process.

Suppliers to the grid will need to comply with one of the UK wide electricity connection standards:

- G59/1/NI: for embedded generators less than 5MW and 20kV
- G77: (now withdrawn & replaced by G83/1 below)
- G83/1: for embedded generators up to 16 Amps per phase

Charges for grid connection vary with the distance from suitable connection points. NIE is working on ready-reckoners to help would-be suppliers understand what these costs might be. In the absence of more detailed proposals, it is difficult to give clear indications as to what costs might be. The closer to suitable connecting points, the lower will be the costs.

As a matter of detail the pricing mechanism for Use of System charges has been reported as being based on the distance of the installation from the secondary substation.

14.3 Compatibility with Known Development Plans

Evidently, any site proposed has to be compatible with development plans. This is the same as for any proposals for waste management facilities.

In the current system, proposals are required to demonstrate that they are (part of) the Best Practicable Environmental Option (BPEO). The Environment and Heritage Department is currently engaged in a national BPEO assessment exercise.

Whilst a noble concept in principle, in practice, one sees everything and anything justified as 'the BPEO'. The process is far from objective. Partly because of this, and bearing in mind some of the studies cited in the previous section, fulfilling requirements of any BPEO assessment ought to be relatively straightforward.

14.4 Compatibility with Known Adjacent Land Uses

The criterion of compatibility with known adjacent land uses reflects the importance of siting the facility in a manner consistent with planning objectives, and minimizing public resistance in the area to the greatest extent possible. This also has implications for the operation of the facility with respect to considerations such as odour control and traffic impacts. Sites located adjacent to known planned land uses that are clearly incompatible should be eliminated from consideration in any search for relevant sites.

14.5 Synergies with Existing Land Uses

Other issues of relevance relate to the opportunities for co-utilisation of certain assets. One of the Case Studies earlier in this report, that of Tilburg, showed how biogas upgrading equipment at a landfill site could be used to clean the biogas from the digestion facility too. Equipment for energy generation from landfill gas could potentially be used also by AD equipment.

To the extent that waste waters may need treatment, proximity to such equipment may also be of use. This raises possibilities for co-digestion with sewage sludge, but in this case, the quality of the end product, in particular in respect of organic contaminants and heavy metals, has to be considered carefully. Whether or not such treatment is needed at all is likely to be determined by the nature of the treatment, future legislation regarding the need for dewatering, and the nature of feedstocks.

It may also be the case that, if separate treatments for kitchen waste (AD) and garden waste are considered, that the requirement for waste water treatment can be reduced through co-composting digestate and garden waste in the aerobic phase. Hence, co-location of aerobic composting facilities and digestion plants may present interesting options with possibilities for blending products to suit specific end-uses.

Lastly, there may be advantages to locate facilities in areas needing grid reinforcement (so as to take up the opportunity of support under the SMART 2 Programme). However, it would probably be foolish to skew decisions to a significant degree on this basis alone. The location must be broadly appropriate irrespective of the presence of the possibility of obtaining financial support. Equally, if such a location can be altered with little impact on the viability of the project, of course, it makes sense to ensure that the proposal can maximise its effective contribution to grid reinforcement.

14.6 Summary

It is not the place for this study to examine site-specific issues for AD sites, other than in the general sense. A number of issues in respect of location will influence costs. However, location is but one of a number of factors affecting costs of AD facilities. Any proposal has to be considered in its entirety, and locational issues have to be considered alongside the range of other factors influencing costs.

There is no reason why, *a priori*, AD systems should not be quite acceptable to the Planning Service from the perspective of BPEO. PPS 11, produced by the Planning Service, discussed AD under 'waste treatment and energy recovery' (reflecting the definitional issues raised earlier in this report). The statement regarding AD is not unhelpful:

> *Other emerging thermal treatment technologies include gasification and pyrolysis. Anaerobic digestion is a further technology which produces energy from the treatment of organic wastes. These technologies involve processes carried out in enclosed plant which limit emissions to the atmosphere. Some of these processes could therefore play a more significant future role in waste management.*
>
> *7.19 For all EfW facilities, proximity to waste arisings, the significant traffic generated and heat and energy considerations point to locations within or close to urban areas with good accessibility to the main road network. It is important that waste is delivered and residues removed in properly designed vehicles to ensure the avoidance of spillages. Significant environmental and economic advantages may accrue when large EfW facilities are located adjacent to rail heads and ports.*[68]

There have been more general questions raised concerning the ability of the Planning Service to respond to applications for planning permission in the field of waste management. Our understanding is that efforts are underway to improve matters in this respect.

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[68] The Planning Service (2002) *Planning Policy Statement 11: Planning and Waste Management*, Belfast: The Planning Service, December 2002.

15.0 SUMMARY AND CONCLUSIONS

This study has sought to examine the feasibility of making use of AD systems for the treatment of MSW in Northern Ireland. The study's scope has been quite broad, and this has made it difficult to examine all possibilities. We have concentrated, in the study, on the source separated organic fraction of municipal waste. In some respects, this is the most difficult feasibility test. Feasibility would be enhanced if other waste streams are co-digested. To this end, to the extent that our conclusions are favourable, they are likely to be more so if one takes account of the possibilities for co-digestion.

15.1 Processes Available

There are a very large number of processes now available, and there are a growing number of systems in place across the EU. These include wet and dry processes, and processes operated at mesophilic and theormophilic temperatures. Most are still one-stage processes.

15.2 The Policy Environment

Generally, the policy environment is favourable to the development of AD. In Northern Ireland:

- The Northern Ireland Heritage Service is reviewing its waste strategy;
- The Northern Ireland Heritage Service is developing its strategy for dealing with biodegradable wastes. This reflects concerns to ensure that the country can meet targets for biodegradable municipal waste under Article 5 of the Landfill Directive, as well as the broader commitments contained in the Directive to ensure a reduction in landfilling of all biodegradable wastes;
- The Department of Enterprise, Trade and Investment (DETI) is developing a strategy for the promotion and development of renewable energy, including mechanisms for enhancing the price received for electricity derived from renewable sources (through what amounts to a system of tradable credits, or green certificates);
- There is some interest, on the part of the principal electricity supply company NIE, in reinforcing parts of the electricity network which are weak.

At the European level, various initiatives at the European level, whilst seeking to ensure that waste derived soil improvers are unlikely to transmit pathogens, are encouraging source separation of biowastes so as to provide feedstocks for the production of quality composts. These include:

- The 2nd Draft of a Biowaste Directive;
- the European Commission's Communication to the Council and the Parliament *'Towards a Thematic Strategy for Soil Protection'*.
- The Discussion Document issued by the European Commission concerning Biowastes and Sludges.

Some issues remain of concern. These include the way in which anaerobic digestion is defined (for the purposes of, for example, the setting of targets for recycling and 'composting'), and the links (or rather, the lack of them) between standard for end products and the freedom to spread composted / digested materials on land.

15.3 Regulatory Issues

One piece of legislation deserves some attention. This is the UK ABPR. This lays down process requirements for AD and composting plants and requires HACCP plans to be prepared for all sites (to ensure that unprocessed material cannot cross-contaminate 'clean', i.e., treated material).

AD plants seem well-adapted to the UK ABPR, possibly more so than most compost plants (because of the enclosed nature of the process, and the 'one-way-flow' nature of the treatment. Hence, the UK ABPR probably has the effect of narrowing cost differentials between compost and AD.

15.4 Case Studies and Plant Analysis

The case studies and plant analysis highlight the possibilities for AD of source separated organic wastes in different contexts.

The plant analysis shows considerable variation in performance (in respect of biogas generation) and in the unit capital costs. This cautions against any easy generalisations of AD processes. Different suppliers seek to make use of residues in different ways, whilst the UK ABPR might require some re-design of processes for different suppliers. Such re-design should not be too onerous given the nature of the requirements, and the nature of digestion processes (frequently generating some heat on site).

On the basis of the financial analysis, the costs for AD are still likely to be higher than for aerobic composting processes. Lower end gate fees for AD – we would expect these to be £45-50 - would correspond with higher end gate fees for aerobic plants. This implies either a need for innovative approaches for integrating AD into waste management systems, or a need to seek to reduce unit costs through co-digesting other appropriate materials.

This analysis could be altered by support through Programmes such as SMART 2, and whilst enhanced capital allowances might be available for good quality CHP, we would expect the effect of ECAs to be of relatively low significance. More important will be the prices received for electricity supplied, and for the residues.

15.5 Economics of Digesting Source Separated Organic Fractions of MSW

Recognising the cost differentials which are likely to remain between composting and AD, we sought to show how maintaining distinct collection systems for garden waste and for kitchen wastes can reduce the cost differential between composting-only systems, and those including AD. This is based upon two key points:

3. The separate collection of biowastes can be an effective tool for cost-optimisation in collection and treatment; and

4. Aerobic systems have to incorporate structural material in the process. AD systems may not (some see it as more desirable than others), though they may need such material in post-treatment aerobic stabilisation.

The importance of biowaste collection and management systems is increasingly well understood. We sought to show how innovative systems are now available for implementation which:

- maintain costs at low levels; and

- ensure that there is no undue increase in collected waste through offering free garden waste collections to households.

We then sought to illustrate how:

a. by considering the collection system as a system, and notably, by considering the integration of biowaste and refuse collections, the costs of separate collection can be kept close to those of existing collection systems;

b. by aiming for high captures through separate collection, because the options for residual waste management are becoming more expensive, the costs of separate collection systems can be kept below what they will otherwise be if the system simply revolves around refuse collection and disposal;

c. by keeping the garden and kitchen waste collections separate, not only is the collection system cost-optimised, but so is the treatment of the biowastes; and

d. last but not least, even where one takes the view that there remains a cost differential between composting and AD, AD can be part of a system which is cheaper than some involving separate collection of kitchen and garden waste for composting only.

These conclusions are of great significance. They point the way towards truly integrated waste management. AD can have a role to play in sustainable systems of this nature without incurring cost penalties.

15.6 Environmental Performance

Environmentally, most studies support the view that AD is superior to composting. The principal reason is related to the generation of energy and the benefits this confers.

Some studies have questioned the degree to which AD should be preferred to good quality incineration. Most of these studies are based upon proposals for collection logistics which simply do not make sense (and differ radically from the cost-optimised proposals we have suggested). Even in these cases, a preference is difficult to discern.

There remain questions as to the degree to which incineration of wet fractions such as kitchen wastes makes any sense at all. Moisture contents are frequently in excess of 70%, implying that what one is sending for combustion is principally water.

As long as collection logistics are optimised, and source separation is such as to ensure quality end products, separate collection of biowastes makes financial and environmental sense. Whether AD is considered superior to composting in an overall analysis has typically been considered a question of cost. In the past, and to some extent still, AD has been more expensive than aerobic treatments. However, as we have sought to demonstrate, canny approaches to cost-optimised collection can fit well with the deployment of AD in waste management systems. Furthermore, the UK ABPR, particularly as it applies to non-catering waste Category 3 material, may make AD an attractive option for these materials.

15.7 Conclusions – Why Digestion?

The short answer to this question is a qualified 'yes'. This is likely to be true for both source-separated organic fractions of MSW (SOFMSW) and the organic fractions of MSW separated from residual waste (OFMSW). In the latter case, there will be question marks over the quality of digestate product produced, both in respect of heavy metal contamination, but also, and perhaps more importantly, in terms of organic contaminants.

Digestion systems are especially interesting in the context of the twin objectives of moving MSW away from landfill, and in seeking to develop supplies of renewable energy. MSW has to move away from landfill-based systems, and not before time, because of the Landfill Directive (and the Northern Ireland Environment and Heritage Department is currently consulting on the implementation of a landfill allowances trading scheme to ensure compliance with the Directive). In this context, the question, 'where should biodegradable municipal waste be diverted to?' assumes great importance.

For biowastes, the options are, broadly:

1. systems based around source separation, with material being either composted or digested;

2. systems based upon mixed waste management, with material being treated through conventional incineration;

3. systems based upon mixed waste management, with material being treated through advanced thermal reatment; and

4. systems based upon mixed waste management, with material being treated through mechanical biological treatment, wither with or without and AD component, and with or without the production of a refuse derived fuel from the high-calorific residual wastes (including non-biodegradable elements, such as plastics, for which ROCs are not available).

AD probably offers the most popular means of recovering energy from the waste diverted from landfill. It can also provide valuable products for use in agriculture. The relatively dispersed population in Northern Ireland does not obviously lend itself to centralisation of waste treatments. Options based upon conventional incineration are unlikely to be either popular, or especially well-suited to the situation in hand (not least since significant economies of scale are unlikely to be available even in the centres of population of Northern Ireland).

These considerations, alongside the fact that a range of other biowastes are likely to be available, makes AD a very interesting technological option for waste management in Northern Ireland. It fulfils the requirements – simultaneously – of both renewable energy strategies and waste strategies, whilst it lacks the poor public image of incineration technologies.

With careful design of collection systems, digestion can play a role in treating the material collected through high capture, cost-optimised collection systems. Suitable market development activities would complement well the development of this technology. The market development process itself will be helped by a focus on high quality products (and hence, appropriate feedstocks) so as to give confidence to end users of what is a very valuable material for application to land.