Composting Technologies and Systems:

Possibilities for the advancement of Scottish Waste Treatment

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1.Background

Composting is the aerobic decomposition of organic waste to produce CO_2, water and a mature, less active waste. Organic wastes are a major fraction of the waste steam. From household waste alone there are over 700,000 tonnes of organic waste arising annually in Scotland and, in view of landfill diversion targets, composting is attracting considerable interest as the principal means of dealing with this waste. The potential for recovery of organic wastes in Scotland is significant provided the right volume and type of processing capacity can be developed

The diversion targets for organic wastes are significant – over 1,000,000 tonnes per annum of waste will need to be diverted from landfill by 2013 to alternative methods of treatment and disposal. The targets will be higher by 2020. Composting is an attract treatment method for the following reasons:

- It is a simple low cost technology, although processing methods can be deployed to encourage the composting process;
- As a familiar process, it is unlikely to meet significant public opposition during the planning process;
- Almost 1/3 of the waste tonnage is "lost" to CO_2 and water through the composting process;
- The resulting compost material can be put to beneficial use on land

There are several very different types of organic waste streams emanating from gardens, households, commercial establishments, grocery stores, farms and sewage treatment facilities. Each organic stream can be processed differently and, at appropriate points in the processing various organics waste streams can be combined to produce a variety of composts with very different attributes.

1.1 Barriers to composting

Despite being a simple process, Scotland has relatively little experience in compost production. So far Dundee has been the most active producer of compost, producing 15,000 tonnes per annum mainly from green waste generated by park departments and households. Within Scotland, there are numerous potential market opportunities for compost, including; urban horticulture, commercial landscape, agricultural, land remediation, soil additives, soil amendments, and bioswale development to name a few. A recent study[2] undertaken on behalf of the DETR indicated a potential market of 0-148Mt/yr based on the theoretical nitrogen requirements for agricultural purposes.

However there are concerns over the use of waste derived compost and such barriers to developing these markets must be tackled. Perhaps the most obvious issues are the variation in quality and the need to develop standards for different applications. Addressing these issues is a complex undertaking and is the subject of much debate in other fora such as the Compost Association, the new Waste Resources Action Programme and the Scottish Compost Development Group.

With the requirements of the EU Landfill Directive, coupled with the existing government municipal waste recycling targets, Local Authorities and private landfill operators face significant challenges to implement sustainable strategies.

1.2 The composting process

There are two fundamental types of composting aerobic and anaerobic:

Aerobic composting is the decomposition of organic wastes in the presence of oxygen (air); products from this process include CO_2, NH_3, water and heat. This can be used to treat any type of organic waste but effective composting requires the right blend of ingredients and conditions. These include moisture contents of around 60-70% and carbon to nitrogen ratios (C/N) of 30/1. Any significant variation inhibits the degradation process. Generally wood and paper provide a significant source of carbon while sewage sludge and food waste provide nitrogen. To ensure an adequate supply of oxygen throughout, ventilation of the waste, either forced or passive, is essential.

Anaerobic composting is the decomposition of organic wastes in the absence of O_2, the products being methane (CH_4), CO_2, NH_3, and trace amounts of other gases and organic acids. Anaerobic composting was traditionally used to compost animal manure and human sewage sludge but recently is has become more common for some municipal solid waste (MSW) and green waste to be treated in this way.

1.2.1 Stages of the composting process:

There are three main stages to composting

- **Phase 1**, the mesophilic growth stage, which is characterised by bacterial growth and temperatures of between 25 and 40 °C.
- **Phase 2**, the thermophilic stage when bacteria, fungi and actinomycetes (first level consumers) present at temperatures of 50-60 °C, breakdown cellulose, lignin and other resistant materials. The upper limit of the thermophilic stage can be as high as 70 °C and it is necessary to hold the temperature at this level for a minimum of 1 day to ensure pathogens and contaminants are destroyed.
- **Phase 3** is the maturation stage, where temperatures stabilise and some fermentation occurs, converting the material to humus through nitrification reactions. Ultimately the objective is to produce a material, which is stable and this can be judged by the carbon to nitrogen (C/N) ratio; a well-composted material has a low C/N ratio. For example untreated new organic waste has a C/N of 30 whereas windrowed material is 15.

1.3 Advantages and disadvantages to composting organic waste:

Composting	
Advantages	**Disadvantages**
Waste is stabilised into form which limits potential for leachate pollution	Unreliable or uncertain product quality
Pathogens are killed, rendering the material suitable for land spreading	Odour problems may occur in process
A source of nutrients	Market perception is low
Significant waste volume reduction	May need large areas of land
Can be used as a biofilter material	

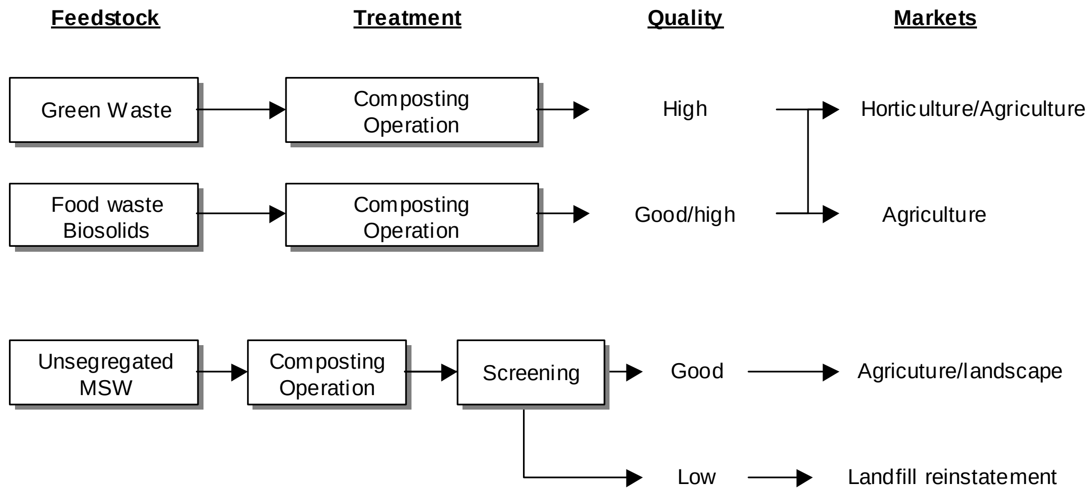
1.4 Types of organic waste commonly used for composting:

Green waste – waste collected by the authority with little contamination when composted can produce a very good quality compost, which can then be supplied to a number of different markets including agriculture, horticulture, landscaping and land remediation

Food waste and Biosolids – Waste from the food processing industry and sewage sludge from the waste water treatment process can, when blended with a good carbon source such as wood, produce a good quality compost. However, this type of waste, other than the putrescible fraction of the household waste, is not subject to landfill diversion targets and is only attractive for composting where the alternative costs of disposal are more expensive.

Municipal Solid Waste – Unsegregated waste from the household waste stream is composted. Shredding of the waste or mixing with sewage sludge may take place together with screening of the final product.

Figure 1: Raw materials, processes and markets for compost



2. Types of Composting

2.1 Home Composting

Of most benefit to the local authority is any form of home composting carried out by the householder. This avoids the waste entering the waste stream in the first instance and therefore removed at no cost by the householder. Some survey work undertaken by the Strathspey Waste Action Network (SWAN) showed that home composting can divert 15% of the household waste fraction, and through active composting of food wastes combined with green waste could reach 30% diversion. However while home composting may seem an attractive option there are some difficulties:

- **Cost of Bins** - Typically £20-30 each, the bins represent a significant investment, and any home composting programme has required the local authorities to offer bins at subsidised levels. Although this is a one off cost rather than an annual charge.
- **Public participation** – It is uncertain how public participation continues over an extended period. Home Composting functions well where the householder actively utilises the composted material in his garden. Use of compost facilities will always be high when the compost bin is being filled.
- **Suitable for all housing** – Home composting is suitable for single housing with gardens, which can combine green waste and food scraps. However, not all housing will be suitable.

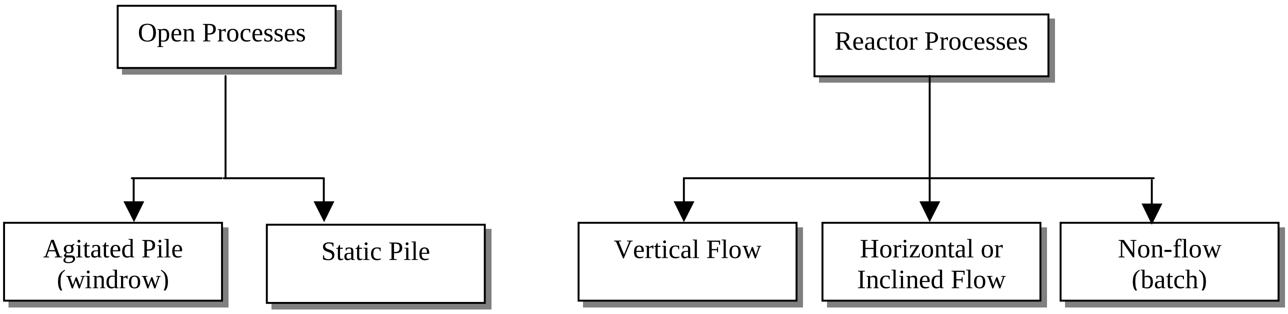
Nevertheless home composting will be an important method for reducing waste presented to the local authorities in some areas. For example, the approximate output for home composting in Argyll & Bute is 3060 tonnes/year. (Ewan MacDougall, Argyll & Bute Council, 2000. Personal communication)

2.2 Centralised Aerobic Composting

The targets for organic waste diversion are such that local authorities need to examine composting operations that will divert several thousand tonnes of waste each year. The different types of composting processes vary significantly. Yet fundamentally there are two systems:

- Open such as in windrow systems where the composting process takes place in the core of the waste where temperatures can be maintained;
- In vessel systems where an “acceleration” of the thermophilic phase shortens the composting period.

Figure 2: Types of composting methods and examples



2.2.1 Open Process

Agitated Pile/Windrow

- Simple method that uses no specialised technology
- Can be used to compost almost any feedstock
- Suitable for large quantities of waste

Waste is pre-treated and heaped into elongated piles which are turned at set intervals depending upon the material and end use. Two common types of windrows are delta windrows, which are set in long triangular piles of up to 2m in height and 2.5-3 m in width, and trapezoidal windrows which are extended rectangular piles with sloping sides, up to 3m high and between 10 and 12m wide. The exact dimensions will vary according to the feedstocks and local weather conditions. Windrows can be either passively aerated or forcefully aerated using perforated pipes running through the mass.

The material is mixed or turned using wheeled front-end loaders or specialised windrow turners. The process can take between 12 to 16 weeks to complete. Temperatures within a windrow can reach up to 70°C, which is sufficiently high to ensure pathogen kill, but often the temperature distribution is uneven with thermophilic zones and microbial activity concentrated in the centre and cooler areas towards the base. Such variation may result in uneven destruction of pathogens and an incomplete reaction.

Table 1: Examples of Windrow facilities

Operator	Location	Feedstock	Output	Markets
Shanks Waste Solutions	Milton Keynes, Peterborough	shredded green waste produce	34,000	gardening, landscaping agriculture
Hanson Composting	Surrey and Kent	garden waste from civic amenity sites	Approximate annual sales to the end of December 2000 is expected to be 300,000 bags.	golf courses, landscaping, land remediation agriculture. garden centres, B & Q.
Levenseat Landfill	Shotts in Lanarkshire	sewage sludge, filter cake from Water treatment food waste, animal waste, green waste, wood waste	between 5,000 and 10,000	spread on a farm owned by the landfill proprietor
Scottish Organic Services	Ayrshire (indoor facility)	seaweed residue from a factory in Girvan		'Blended Seagrow' product is mixed using a feed mixer, and sold to golf courses.

Static piles
An alternative method of windrowing is the **Beltsville aerated rapid composting (BARC) system**. A mixture of sludge and wood chips are composted over a porous foundation of compost and wood chips. Pipes are running through the pile to allow aeration of the mixture and ventilation may be either natural or forced (i.e. under positive or negative pressure). One example of a naturally ventilated static pile is the **Chinese Composting Pile**, which consists of punctured bamboo poles running through the waste and emerging at either end. This traditional technique has been used in China for thousands of years to compost human and animal manure and vegetable waste. The surface of the pile is covered to prevent heat loss during the process, which takes around 60 days. Forced ventilation of the pile is by connecting the aeration pipes to a fan.

Table 2: Examples of Static pile facilities

Operator	**Location**	**Feedstock**	**Input (tpa)**	**Output**	**Markets**
Consorzio Milano Puilta (CECCINI process)	Milan, Italy	MSW only	5,475,000		
VAROM	Osnabruch, Germany	shredded, screened MSW			landfill cover

2.2.2 Reactor processes (in-vessel or enclosed)

Vertical flow

- **Agitated solids**

Vertical flow systems such as the **JERSEY** system, used in Bangkok, Thailand or the **Silo-cage system** from **TEG Environmental plc**. (England), are essentially facilities with multiple floor construction which employ an aerobic process. In the case of the **Silo-cage system** , the floors consist of a collection of up to 30 stainless steel perforated cages. The cages are installed apart to allow for passive aeration, eliminating forced ventilation and turning.

The feedstock is screened to eliminate unsuitable non-compostable waste and is loaded onto the uppermost floor of the building to begin the composting process; aeration occurs as the material moves downwards. As the product is added to the top floor or cage, it is warmed by the existing material creating the hottest part at the top of the container. Because the material is already hot, the process is ‘jump started’ leading to a shorter residence time in the container. As the material works its way to the bottom of the cage the temperature gradually lowers. Once removed the compost is matured for up to three weeks.

The composting time varies from 8 to 21 days and varies with each individual installation, feedstock used and quality of product required. As this type of composting is vertical in design, the site area can be relatively small although provision must be made for the maturation area.

- **Packed bed silo reactors**

Silo reactors, such as the **IBR** process situated in North Vancouver, process solid and liquid feedstocks, consisting of up to 20% inorganic waste and high in containments. Feedstock is sorted and can be mixed with waxed cardboard waste to provide the correct balance of liquid and solid material, as per the customers requirements. During the primary thermophilic digestion, stage the slurry is aerated and shredded and secondary digestion continues in silo like containers. The resultant slurry is filtered, dried and formed into pellets. The process is completely automated with built in biological filters to remove odours. The IBR plant covers a minimal area of 1 acre (approx. 0.4ha).

Horizontal flow

- **Tumbling solids (rotating drums)**

A horizontal flow composting process such as the **Bedminster** co-composting process is suitable for composting MSW and sewage sludge together. The digesters can handle up to 60 tons of MSW and 30 tons of sludge per day. After sorting and mixing, the feedstocks are transferred to the digesters i.e. rotating drums divided into three compartments and pitched at a slight angle to allow the waste to travel along the system. Each compartment holds 90 tons of waste a day therefore, when full each digester is composting 270 tons at any one time, in a continuous batch system. The waste travels through with the help of small scoops, and is removed daily from the end of the tunnel. Each time a batch is removed the one behind it is transferred to the following compartment. The process operates at between 65-71°C for two days which ensures that all pathogens are inactivated. Air is introduced to the process by pumping from the end of the digesters and so flows in the opposite direction to the waste.

As the pumped air reaches the beginning of the process, it has gained heat from the thermophilic stage in the middle compartment, thus on contact with the new cold feedstock the heat and moisture in the air is released kick starting the new material. Exhaust air is treated is treated to remove unpleasant odours obtained throughout the process. A further 28 days is required for maturation, after which the material is screened and any remaining inert materials are removed. The final stage grades the product into soil fractions ready for use.

- **Mobile Drum Composters**

Mobile drum composters developed by **Augspurger Engineering Inc.** are currently undergoing trials in Sydney Australia. This type of system is aimed at small businesses, prisons or small islands which compost waste on-site but where an industrial composter is too large and a home composter is too small/slow.

The first type of drum is situated on site at the source of the waste and operates on a batch process, composting approximately 909kg's of green waste food scraps, paper, or sewage sludge. The drum can be tilted up to 10° and rotates at 1 rpm taking approximately 20-30 days to complete the cycle. Daily aeration is recommended and can be either manual or automatic. Exhaust air filtration can be incorporated if necessary. The second type of rotating drum composter has a capacity of 7.6-76 m^3, operates a mobile continuous process with a and can be transported by trailer.

- **Combined Rotating Drum and Static solid aerated pile**

TransAlta in Edmonton, Canada, operates a system that combines the Bedminster, drums to mix the feedstock, with the Sorraine CECCINI system to compost the material. The system is still receiving waste in order to fill the plant completely.

Feedstocks are sludge (28% solid) and MSW, which are mixed in the drums to prepare for composting. After passing through the drums, the material is screened and moved via conveyor to CECCINI composting bays for a final composting time of 28 days. The composting bays have sub-bays with aeration ducts incorporated into their gravel base. This aeration not only introduces oxygen to the process but controls the temperature of the material. After the Sorraine section the compost is screened with trommels to remove plastic and grit. The final stage is outdoor maturation or curing. Any leachate is treated with a VOC stripper, which transforms organic residues into particulate air borne material that is thermally combusted (Baird, 2000).

TransAlta hope to sell this compost (OrganagrO®) to the agriculture industry and Currently, it is used to remediate an area of the adjacent contaminated landfill. (Baird, 2000 & Bedminster Bioconversion Corp, 1999)

- **Aerated in-vessel**

For an aerated in-vessel system, the material is loaded into the reactor to a depth of around six feet and the waste is then moved through the container continuously enabling an uninterrupted process. There are two 'composting zones' where bacterial decomposition occurs, the first is aerated and vented and optimal temperatures are maintained until, after 6 days, the material reaches the 'mixing zone', where the waste is scooped and thrown forwards to the second 'composting zone', This further aerates the mass and adds moisture. Mixing ensures a sufficient distribution of bacteria in order to continue the process in 'zone two'. The material remains in the container a further 15 days as the composting waste moves along the container to the 'unloading zone', where the reduced temperatures signify the process is complete.

Wright Environmental Inc is a Canadian company, designed such an in-vessel system for the treatment of source separated MSW, biosolids, paper pulp sludge and also contaminated soil. When treating MSW the waste is mixed with a combination of wood chips, yard waste, newsprint and paper towels depending on what is needed to provide the correct ratio of carbon to nitrogen. The material produced is used as a soil improver or 'replenisher'. All the exhaust gases from the system are treated in a bio-filter prior to discharge. Individually tailored plants can be designed with interchangeable container numbers and variations in size of the units. The economical use of land means situating such a plant in an urban area should not be a problem. (Wright Environmental Management Inc.)

The **Silsoe Research Institute** is investigating pig manure and straw composting at its site in Bedfordshire. Twenty-four hours prior to composting the manure and straw are mixed with a urea solution. Together with water the materials have a C:N ratio of 30 and M/C of 70%. The feedstock; is mixed 1:2.4 manure to straw and loaded into the vessel. The container holds 212 litres of feedstock, which is composted for 14 days. Aeration is provided to maintain the temperatures at between 55-60°C this is controlled by thermostats enclosed in the container. The final product, is spread on farmland, and is not planned for horticultural use. (Cronjie, 2000. Personal communication)

- **Agitated bins**

This is an enclosed system where shredded and blended waste is moistened and loaded into an agitated container with temperature, CO_2 and air circulation controls. Air enters through the base of the container into the compost mass and exits through the roof via a filter. The process takes between 7 and 14 days followed by a maturation period of up to 12 weeks.

Examples of such a system include the **Alpheco** batch system and the **Rottebox** system (HERHOF (Germany), part of the HUWS Corporation) which is in operation in Beilstein near Frankfurt. At this plant 21,000 tonnes per year of MSW (80%) and green waste (20%) are composted using 14 Herhof boxes. Each box has a capacity of $60m^3$ and can process a maximum of 1,500 tonnes of material/year.

Waste from the facility is completely treated on-site, liquid waste is decontaminated by microbiological filters and gaseous waste is passed through a ceramic adsorption filter, which removes odours. Herhof sells the product to cemeteries, golf courses and landscaping firms. Herhof also has plants at Aβar in Germany, eight plants in Austria and one each in Canada , Luxembourg and Belgium. In total, Herhof Rottebox plants comprise 36% of composting plants in Germany. The company also provided a system for a composting project in Ross and Cromarty, Scotland which was to process 3,000 tpa in 1996 but the operation is currently suspended .

- **Tunnel shaped static solids (semi-enclosed)**

Plus Grow, a company based in Manchester have developed a composting system which uses tunnel shaped bays 70m long, 2,1m wide and 2,75m deep. The first plant in the Blackpool area was commissioned by Frank Smith Waste Disposal and uses feedstock collected via kerbside green and household waste scheme. The tunnels are semi open with a roof supported 1m above the top of the walls. The floor of the tunnel has a slope of 600mm to allow leachate to flow to a collection system at the end of the bay. The system composts MSW and commercial organic wastes and can process up to 5,000 tpa, with a planned capacity of 15,000 tpa. Eventually the operators hope to include sewage sludge and co-compost it with MSW. The bays are separated by reinforced concrete walls; a rail runs the length of the wall on either side transporting a shredder/mixer back and forth chopping, mixing and aerating the waste to prevent clumping. Temperatures reach up to 40°C in the receiving bay prior to the waste being transferred to the 'tunnels', where temperatures reach 70°C. The shredding/turning process is carried out every second day, moving the waste 5m down the tunnel with every cycle. The process takes 28 days and approximately 20 tonnes of material can be loaded into the bays every second day with around 12 tonnes of compost being collected bi-daily from each bay. The system is semi-automatic and can therefore be operated with minimal manpower. Plus Grow estimate the cost of operating to be approximately £10/tonne. (Wastes Management, 1999)

Orleans Council in France has also employed a tunnel composting system to compost screened, separated and shredded MSW. The waste is screened to 100mm and moved by conveyor to the tunnels or bunkers where it is sprayed with water and deodoriser. Aeration is achieved by sucking air though the material, this is then recycled back through the system along with the water. Mechanical turning is carried out daily throughout the 8 weeks, then the compost is shredded by a "Tollemach" grinder and screened by a trommel to 10mm. The resultant material is dried for a further 2-4 weeks. Approximate throughput is 15,000 tpa.

Non-flow - Batch tunnels

Dutch company **Gicom's** tunnel composting system is situated at Anglian Waters Cliff Quay Wastewater treatment plant near Ipswich. This tunnel system is completely enclosed allowing a high degree of control over process temperatures. Waste is pre-composted and mixed before loading into the tunnel, (30m long, 5m wide, 5m high) at a critical load of 1.1 tonnes/m^2 of floor area and 2m depth. Aeration is pumped through holes in the floor, which run the length of the tunnel, and extracted via a closed system and either re-circulated or treated by a scrubber then a biofilter. Water is added if required. This system composts Ipswich Borough Councils MSW and sewage sludge cake from Anglian wastes Cliff Quay water treatment plant. The plant cost £1.7 million in 1996, including all machinery needed to pre-process the material.

2.3 Anaerobic Composting

An alternative to aerobic composting is an anaerobic/aerobic-combined system developed by **Steinmüller Valorga** in France and Germany . The system is specifically designed to compost organic MSW and sewage sludge. The first anaerobic stage treats waste with 25-35% solid content to which a little water is added. Waste is first segregated to remove un-compostable items then loaded into the reactor where the solid waste is changed by hydrolysis into liquid. Methanogenesis and, consequently the production of biogas, also takes place in this same reactor thus allowing biological activity to proceed undisturbed. As the system is completely enclosed, gas is collected and piped directly to the electric generator.

Biogas produced during the process is pumped into the digester at high pressure from the base thereby providing mixing without costly mechanical parts. Digestion takes between 2-4 weeks and is carefully controlled to ensure complete sanitisation. Once this process is complete, the material is drained freely from the base of the digester. Because there are no mechanical parts, the digesters can be used continuously without cleaning. After digestion, the material is transported via screw press and filter, dry material is removed and aerobically composted for 2 weeks. Slurry is sent to denitirifcation tank then to a aerated Nitrification tank for aerobic maturation, any remaining product is settled and dried, waste water is treated or re-circulated. All gases are treated in an air treatment unit.

In 1995, there were fewer than 20 plants operating anaerobic systems throughout Europe (Table 4)

Table 4: Biogasification plants in Europe (White et al., 1995)

Country	Location	Process	Feedstock	Capacity (tpa)
Belgium	Ghent	DRANCO	Pilot plant	100
Belgium	Brecht	DRANCO	VFG + paper	15 000
Denmark	Helsingor	BTA	Bio waste	20 000
Finland	Vaasa	DBA-VABIO	Bio waste plus sewage sludge	14 000
France	Amiens	VALORGA	MSW	100 000
France	La Buisse	VALORGA	Bio waste	16 000
Germany	Garching	BTA	Pilot plant	1000
Germany	Kaufburen	BTA	Bio waste	2500
Germany	Zobes	Zobes	Bio waste plus agric. Waste	10 000
Germany	Bremen	AN-Maschinenfabrik	Pilot plant	
Germany	Landkreis	AN-Maschinenfabrik	Bio waste	3500
	Oldenburg			
Italy	Bellaria	Solidigest	Bio waste plus sewage sludge	20 000
Italy	Verona	Sanamprogetti	MSW	50 000
Italy	Avezzano	Sanamprogetti	Sewage sludge	10 000
Italy	Bellaria	ITALBA	MSW	30 000
Netherlands	Breda	Prethane	Veg. Market waste	20 000
Switzerland	Rumlang	Buler AG	Bio waste	3500
		KOPOGAS		

3. Developing a composting strategy

3.1 General Considerations

Clearly each type of composting has its place in different waste strategies. In deciding, which is the most appropriate; the following has to be considered:

- **Feedstock type –** Green waste collected at source or from civic amenity sites is generally going to produce the better quality of compost. As such it is better able to attract some market value.
- **Shredding of waste** – can be an expensive operation, even if there are few contraries in the waste. Shredding also disseminates contamination into the waste, making it more difficult to screen the composted material at a later stage.
- **Screening –** before and after composting screening can improve the quality of compost, making it more acceptable to the markets.

- **Scale of operation –** Large-scale operations (>100,000) will require several hectares of land.
- **Compost standards** – While numerous standards have been developed, no market has yet to recognise any one standard. The suitability of a compost for a market is determined on a case by case basis.

3.1.1 Additional consideration for composting strategies in Scotland

- **Climate**

The relatively cold wet climate in Scotland will present problems to open composting systems, possibly affecting temperature control.

- **Population distribution**

Despite being a small country in relation to others in Europe, with most of the Scottish population living in cities, there is still a substantial proportion of rural population. Islands, for example, have very specific needs when it comes to choosing a composting system (Szmidt & Baird, 2000). Space is limited and islanders will have to consider impacts upon the tourist industry, so discrete facilities are required. For urban areas composting will have to conform to strict odour and leachate controls more so than rural facilities.

- **Transport costs**

Transport costs will be a major consideration when debating the location of a rural facility, as the feedstock will come from a wide area. The target for composting in Scotland is 1 million tonnes by 2010, therefore operators in each area will have to plan the capacity of each plant accordingly. The introduction of several local collection points with an uplift bi-weekly to the main composting site will help reduce transport costs.

- **Proximity of markets**

Scotland still has an important farming industry, which, if approached correctly could consume much of the compost produced. Other important industries include the land remediation sector; Scotland has a disproportionate area of contaminated and derelict land. Since compost is cheap in comparison to many remediation techniques and has been shown to improve, even the most heavily, contaminated soils this could be an important market for Scottish compost.

Table 5: A survey of Scottish Local Authority composting arrangements (Summer 2000)

Council	Tonnes per annum	Method	Details / supplier / manufacturer
Aberdeenshire	-	In-vessel	Wright Environmental
Angus	3139	Windrow & home	240.36tpa from home composting
Argyll & Bute	3385	Windrow (some vermicomposting)	325tpa from home composting. Community composting- vermi & windrow
Clackmannanshire	-	Shred & compost park waste	Free public uplift of compost
Dumfries & Galloway	440	Home	4432 households, (estimated at 100t per household)
East Dunbartonshire	-	Home & de-watering street sweepings	Pilot scheme to incorporate solids into composting system
Edinburgh City Council	450	Windrow & home	Separated at source and shredded. Millfields.
Falkirk	2000	Shred/windrow	Shredded in tub grinder
Fife	-	-	Revising strategy
Glasgow City Council	-	Trials of separate kerbside collection bins. Chipped then windrowed	400 green waste bins, to be extended to 1200.
Midlothian	-	Home	Planned centralised Italian system 2002.
Moray	-	Planned	In conjunction with a

			local farmer. Trials at Aberdeen University.
Perth & Kinross		Civic amenity & kerbside collection. Home	1000 home compost bins. Composting at local landfill. Incentive shemes.
Stirling	1000	Windrow & Home	Chipped & turned
*East Ayrshire and Scottish Borders do not currently operate any composting			

3.2 Merits of each type of systems in relation to Scotland

- **Agitated solid**

As the current preferred method of composting in Scotland, **windrows** involve very little infrastructure or capital investment . It is not labour intensive and requires little technical or specialist knowledge. This method can be operated on a large or small scale depending on the area, but in comparison to other in-vessel techniques, it can be land intensive.

Windrowing has the obvious benefit of being relatively easy to operate. However, the climate in Scotland leads to excessive run-off and decreased temperatures which could reduce microbial penetration of the windrow, limit the thermophilic stage of the process and result in incomplete pathogen inactivation.

- **Static solid**

The **BARC** and **Chinese systems** with incorporated aeration could reduce the need for mechanical turning and thus reduce the machinery needed; nonetheless, it is still an outdoor operation open to the elements and leachate production. The process may progress faster due to the forced aeration and consequently the material will require less time outdoors and could be bagged and used sooner.

Currently the compost produced by **Scottish Organic Services** is an indoor operation and so is more suited to the climate in Scotland. The **VARON** system using a heavy cover material prevents the finer compost being blown away and the pile is on a concrete floor facilitating leachate collection. The sucking method of aeration enables the waste air to be either recycled or treated thereby reducing odours and making it suitable for plants situated in towns or cities.

- **In-vessel or enclosed systems**

These systems are more intensive and therefore involve less space and time. The environment within the vessel is controlled allowing the waste products to be treated thereby reducing unpleasant smells. An enclosed system such as the **JERSEY** is more often found in third world countries, the land required is small as the process is conducted vertically, however the outdoor maturation stage involves a larger area of land and may also be malodorous. The colder temperatures in Scotland may hinder the final stage making it less suitable.

The **TEG Silo-cage** is another interesting possibility owing to its contained structure. It is a continuous semi-automatic system and can be expanded easily, no forced aeration or turning is employed therefore minimising electricity consumption. Shredding is incorporated as the material is loaded and the material therefore only requires basic pre-treatment. Unfortunately, the structure itself is highly engineered and may be comparatively expensive. It seems it would be equally well situated in a large warehouse or outside, allowing scope for use in a damp environment. Since the system is modular it could be built on a scale appropriate to requirements and would be suitable for centralised composting in a town or city.

- **Rotating drum composters**

Bedminster drums therefore could be a real player in the Scottish industry when - as in Edmonton Canada – the drum system is combined with the **CECCINI** system for maturation. Bedminster drums compost 297 tonnes at a time but these systems are still relatively compact. **Bedminster**, **Rondeco** and **DANO systems** are all similar except that the Rondeco uses aerated beds for maturation. The indoor aerated bays, protected from the weather are an advantage to composters in Scotland.

The mobile **Augspurger** composters are flexible in several ways:

- They can be built or multiplied to meet a small island or remote area's specifications.
- It is easily towed around and can be situated where it is needed.
- It is simple to operate and does not require a great deal land or technical knowledge.

This may well be an useful system for Scotland, and could be used in many parts of the country and possibly incorporated with another system say the **BARC** or **VAR**, aerated pile systems, either as pre or post treatment.

- **In-vessel silo reactors**

The **IBR** is an intensive system with both complex infrastructure and operation suggesting a high capital input and operating requirements. However, the ability to process both solid and liquid organic wastes may be useful under certain circumstances. The land requirements are low only 0.4 ha but unfortunately, the plant is visually intrusive and may be unpopular in urban areas. Since the feedstock is liquefied prior to processing, the feedstock could be onsite in large quantities for days or weeks without any effect to the consistency of the final product. The plant would then require to be situated in a more rural location to avoid odour infringement.

One benefit particular to this system is its use of waxed paper and cardboard, both difficult materials to recycle. The pelletised product is another appealing factor of this system, when used in agriculture it could be spread using existing machinery. In addition, IBR claim to treat highly contaminated material at their plant in North Vancouver. This could therefore be used as an alternative to landfill to process material removed from contaminated land sites.

- **Horizontal agitated bins**

Other large and intensive systems are the **Wright In-vessel and the Herhof Rottebox**. These appear to be very compact and efficient systems. Both are enclosed, with the process air contained and treated in a simple biofilter making them suitable for urban areas and resistant to the weather. Each plant can be designed and built to the purchasers specifications, ensuring the system is tailored to the community it serves. Units are transported to the site on a low-loader, therefore this system is flexible and can be taken to an island with minimal transport cost.

The **Alpheco Aergestors** and **Herhof Rottebox** systems are both modular and appear similar in size. The Herhof box is constructed from concrete and the Alpheco Aergestor, is made from metal. Units numbers can be varied to suit the specific volume of each site. A Herhof plant with 14 boxes can compost 21,000 tpa. Both the Herhof box and the Aergestor have enclosed air treatment facilities which will help reduce odour problems. Similar in design is the Silsoe biosolid composting system, which could be useful in rural areas where there is a large volume of animal manure to treat.

- **Tunnel and non-flow batch tunnels**

These systems are technically simpler than the in-vessel reactors, however they do not seem to be any less effective. The **Plus Grow**, semi-enclosed system, is combined with a pre-composting stage that shortens the retention time in the actual tunnel, requiring only minimal manpower. The tunnel is sheltered from the weather by a raised roof but not completely enclosed so still allowing the ambient moisture to enter the process. Having undergone both trails and initial commercial operation, this system seems to be proven in composting MSW and would be suitable for a council or large MSW contractor to install as part of their operation either to reduce the volume of waste or to produce a valuable compost.

Advantages of the **Gicom** enclosed batch tunnel are complete control over the environment inside and the ability to aerate the tunnel as required to determine the type and quality of the compost produced. Sewage sludge is incorporated into the system giving a high nutrient product. At 30m long the plant is not small but has a capacity of approximately 163 tonnes can recycle most organic wastes. This system is also appropriate for councils or waste contractors.

- **Anaerobic composting**

In order to meet the landfill directive target to reduce methane (biogas) production, the Steinmüller Valorga anaerobic composting system may be selected. This system is designed to produce biogas, which is re-circulated through the digesters and then used to generate electricity. There are numerous Steinmüller plants in operation throughout Europe which suggests that the system is effective, perhaps a consideration when selecting a technology for use in Scotland. However, this system could be extensive therefore requiring large areas of land.

- **Home composting**

In addition to the centralised sites, it is important not to overlook home composting. Home composting can make an important contribution to the total volume of waste composted. Not only will it help reduce the volume of waste transported to disposal sites it will help introduce waste awareness to the public. Schemes currently in operation have shown some success.

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