Mechanical Biological Treatment – Solution or Hype?

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ABSTRACT

Mechanical Biological Treatment (MBT) is playing an increasingly significant role in the UK and Europe for the treatment of mixed residual municipal solid waste, as a viable alternative to incineration-based energy from waste treatment solutions. There are numerous generic types of MBT; many of those planned in the UK produce a solid fuel and may also have an anaerobic digestion stage producing additional energy from biogas combustion. MBT also aims to recover some recyclable materials.

Whilst MBT may be seen as a favourable option when compared with incineration, the authors' experience with the procurement of waste treatment processes in the UK indicates that there are issues associated with MBT solutions that need to be considered before it can be universally accepted as preferable to incineration. The limitations of MBT that should be considered when evaluating waste treatment options, to ensure any long-term contracts are suitable, sustainable and affordable.

1. INTRODUCTION

Mechanical-biological waste treatment (MBT) has been operated in European countries since the early 1990s where it has vied with incineration in the more developed countries as the preferred alternative to landfill, post recycling. Incineration has generally been favoured, a cheaper and established technology, but MBT demand is 'higher than ever before' according to a recent study by ecoprog (2011). The UK has had a historical dependence on landfill with some incineration. However, more recently in the UK the drive for MBT rather than conventional thermal treatment capacity has been witnessed, based on a number of significant trends sweeping the UK and wider EU markets.

In 1996/7 local authorities (LAs) in the UK collected about 29 million tonnes of municipal solid waste (MSW), most of which was disposed of by landfill and only 1.9 million tonnes was recovered or recycled (Defra 2012). As a result of several key drivers, such as climate change, renewable energy and resource efficiency agendas, rising disposal costs etc. the UK has introduced policy and legislation that has significantly reduced the amount of MSW landfilled. In 2009/10 the UK generated slightly more (32.5 million tonnes) MSW of which 12.4 million tonnes was recovered or recycled.

This change has involved significant and continuing investment in new waste management infrastructure by LAs including increases (and planned increases) in the collection of recyclables, composting of green waste and anaerobic digestion of food waste. This has been supported by Central Government fiscal policy with a tax on landfill, statutory targets for landfill diversion and research and demonstration programmes to test new treatment technologies.

The residual MSW remaining after source segregation for recycling, which comprises about 40 – 50% of the total MSW arisings, is essentially a mixture of waste materials such as paper, plastic, metals, glass, kitchen and garden wastes and other wastes that the householders have not put for separate collection. MBT processes compete with incineration (energy-from-waste) technologies as the main means of managing the residual MSW stream in the UK.

The use of MBT is not uniform across Europe, MBT has historically been used as a reliable MSW conditioning approach prior to landfilling in Germany, Austria and, to a lesser extent, Belgium, the Netherlands, and Luxembourg. In Switzerland, and the Scandinavian countries, thermal treatment is dominant on account of national legislation and because priority has often been given to a well-established thermal treatment system with heat production for use in local communities.
In the UK, incineration, even though a less costly option, is not always acceptable to the public, due to perceived air pollution and human health risks, and consequently MBT has become an important component of many local government waste management strategies in the UK and more widely around Europe.

At present there are 330 operational MBT plants in Europe, this is expected to rise to about 450 by 2016 (ecoprog 2011). In the UK there are currently about 20 operational MBT facilities with at least another 20 more planned that range in capacity from about 50,000 to as high as 400,000 tonnes per annum.

MBT designs vary but basically comprise MSW processing by a combination of mechanical operations, such as particle size reduction and separation of different components, and biological treatment such as composting and anaerobic digestion. This combination can lead to many potential outputs such as a solid recovered fuel (SRF), refuse derived fuel (RDF) and biogas fuel, recyclables such as ferrous and non-ferrous metals, glass and plastics, and compost like outputs (CLO) that may have application in land restoration or as a soil amendment. MBT may also produce a biostabilized waste (post composting) with a lower mass and biological activity than the untreated MSW and which is therefore more acceptable and cheaper to dispose of in landfills.

MBT designs implemented (or planned) in the UK cover this wide range of options and have been selected through a number of public procurement processes, often using a competitive dialogue approach, run by individual (or groups of) local authorities. These processes aim to select an MBT solution that is best fit in terms of cost, social acceptability and operational design (performance) for the local area it serves.

In Ricardo AEA's role as Technical Advisors to local authorities going through such competitive processes the company has been able to evaluate many different MBT designs in terms of their processing principles, outputs generated, environmental issues, and their limitations. In this paper all of these aspects of MBT will be discussed, drawing on the authors' hands-on experiences from the UK.

2. THE LEGISLATIVE CONTEXT

As a member of the European Community (EC) the UK's environmental legislation is derived from Directives, Decisions and other notices from the EC. Such EC legislation is adopted into UK regulations through Statutory Instruments (SI).

The Waste Framework Directive (WFD) 75/442/EEC presented overall objectives concerning waste management and was an overarching directive from which several daughter directives followed. The WFD has been amended on several occasions with the most recent major revision (Directive 2008/98/EC) in 2008, commonly referred to as the Revised WFD (RWFD). Key waste management obligations from the RWFD are to re-use and recycle a minimum of 50% of household waste (by weight) by 2020. There is also an obligation to re-use, recycle and recover 70% of non-hazardous construction and demolition waste by 2020. Finally, there is an obligation to select the most environmentally favourable waste management solutions, taking due note of a waste hierarchy (Figure 1), which indicates a preferential order of waste management options.

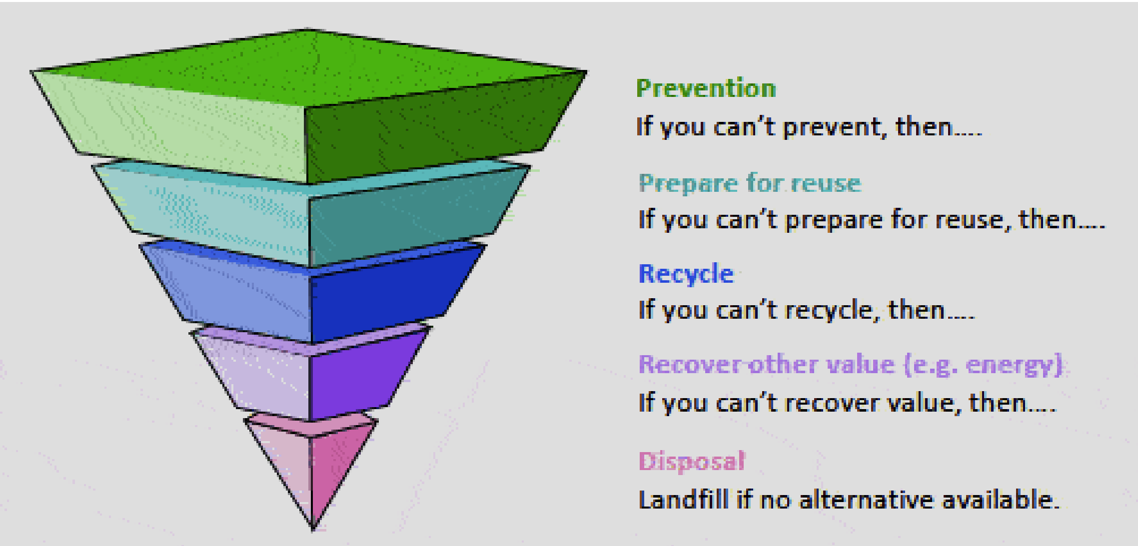

Figure 1. The Waste Hierarchy

There is justification however for using a lower ranked approach if it is environmentally better in terms of the carbon footprint. Hence in the UK, anaerobic digestion of food waste (recovery) is preferred (by policy makers) to composting of food waste (recycling) on such grounds (Defra 2011c).

The Landfill Directive (1999/31/EC) requires the progressive diversion of biodegradable municipal waste (BMW) from landfill in order to reduce fugitive emissions of CH_4 from landfills. When translated into UK legislation the resultant targets for reducing the amount of BMW landfilled were set - 75%, 50% and 35% of 1995 values by 2010, 2013 and 2020 respectively. A recent clarification has defined BMW in this context to include all biodegradable waste collected by LAs and other similar Commercial and Industrial (C&I) wastes (Defra 2011d).

The European Union has committed to reducing greenhouse gas (GHG) emissions to 20% of 1990 levels by 2020 and to 30% if other countries make similar pledges.
The UK itself has made the commitment to reduce GHG emissions to 34% of 1990 levels by 2020 and by 80% by 2050 (UKGOV 2008). The EU Renewable Energy Directive (2009/28/EC) also requires that members produce 20% of their energy as renewable energy by 2020. The UK (through the Renewables Obligation Order 2011) has increased its target to 30%, noting that non-fossil carbon derived organic matter in waste is considered as a renewable energy source to help achieve these targets.

These targets may be achieved through the generation of combustible solid fuels (which may include some fossil carbon derived organic matter), and gaseous fuels such as syngas from gasification/pyrolysis thermal technologies and biogas from anaerobic digestion. These climate change and renewable energy targets are very challenging, especially as the UK population is expected to continue to grow over the next 25 years from 62.3 million to 73.2 million in 2035, thus increasing household energy demand (ONS 2010).

The UK government has introduced several fiscal initiatives promoting the use of waste as a resource to meet the requirements set out above. One key action was to introduce a landfill tax on waste landfilled, which was increased annually by £8/t, until it reached £80/t in 2014/15. There is a floor under the current rate, so the tax cannot go below £80/t until after 2019/20. This has meant that whereas landfill has historically been the cheapest waste management option in the UK this is no longer the case, and recovery options are now economically viable in comparison.

The introduction of Renewable Obligation Certificates (ROCs), the Renewable Heat Incentive (RHI) and Feed in Tariffs (FITs) have provided specific financial incentives to develop energy and heat recovery from waste at both large and small scale facilities (DECC 2012b, DECC 2011, DECC 2012a, EST 2012). However, it should be noted that the details of these incentives have been modified over time (sometimes favourably and sometimes not) which creates a level of uncertainty for funders and operators alike, that has slowed down many planned developments.

3. MBT SYSTEMS

There are many different designs of MBT which are configured to produce different product outputs in different proportions whilst retaining some degree of flexibility. MBT designs may be proprietary designs from whole system suppliers, consortia of major suppliers or self-build systems based on bringing together several readily available processing units. The latter may be attempted for small scale operations <40,000 tpa whilst the former are typical for larger throughputs.

Six generic MBT systems are recognised in the UK which cover a wide range of bespoke and commercial designs. The example MBT systems discussed below are for illustration purposes only and are not an indication of preference for any supplier.

3.1 MBT with RDF production and composting (RDF+C)

Here the incoming waste is coarsely shredded and a dry combustible fraction of mainly plastics, paper, card, wood and textiles is screened off as the refuse derived fuel (RDF). Depending on the composition of the feedstock the RDF fraction may account for up to 40 - 60% of the input feedstock mass. Typically the RDF has a net calorific value (NCV) of between 11 – 15 MJ/kg which is higher than the residual MSW (8-10 MJ/kg) that might be combusted directly in an energy from waste (EfW) facility. As with virtually all MBT facilities, metals (ferrous and non-ferrous) are usually recovered (2 – 5%) on the input mass. The initial processing may also recover some of the plastics as recyclable products (up to 6%), although this would detract from the mass of RDF and its NCV.

The residue, consisting mainly of the wetter putrescible material such as garden and food waste, is composted for an extended period of several weeks to stabilize the residue for landfilling.

The stabilized material may be refined to produce a compost-like output (CLO), of up to 20% of the input mass, which may be used for land restoration or potentially as a biomass solid fuel. This refining process may also produce recyclable aggregates derived from the glass, stones, bricks and ceramics in the residual MSW (up to 7%) of the input. If outlets for the RDF and composted residue can be secured this MBT design will virtually divert all the incoming waste from landfill.

3.2 MBT with RDF production and anaerobic digestion (RDF+AD)

This MBT configuration is similar to RDF+C except that the organic rich putrescible fraction is anaerobically digested rather than composted. This has the advantage of producing energy from both the dry combustible fraction as RDF and from the wet putrescible fraction. This MBT configuration is one of the most popular configurations being implemented in the UK partly due to the promotion of AD by the UK Government. For example 5 MBTs of this configuration are planned for the treatment of residual waste by Greater Manchester Waste Disposal Authority, the largest Waste Disposal Authority in the UK. Two of the MBTs employ Enpure AD technology and the other three Haase AD technology. A key issue with this MBT configuration is management of the digestate which is a high moisture content organic residue (as discussed in the next section).

3.3 MBT with anaerobic digestion and recyclate recovery (AD+R)

In this novel design, the waste is first mixed with water and undergoes a mechanical wet separation process. During this processing most of the biodegradable waste including food, green, paper and card wastes are macerated into sludge, and the recyclables such as metals, aggregates and plastics are removed and washed as clean recyclates. The remaining sludge is then AD treated. Consequently this MBT configuration maximises recyclables (up to 25% of input for a typical residual MSW) and biogas production although significant amounts of digestate are produced which may need further processing. One MBT is under construction in the UK of this design using ArrowBio technology at Falkirk in Scotland.

3.4 MBT with Biodrying and SRF production (BD+SRF)

Here the waste is first shredded and then the whole waste composted for a short period of 2 to 4 weeks. Composting is facilitated by a high air flow rate forced aeration system, which combined with the heat generated by the microbial activity results in significant drying of the waste. The biodried waste is then subjected to the main mechanical step which typically would produce a SRF (up to 60% of input), recyclates such as metals and aggregates (up to 8%), and a reject material for landfill.

The SRF quality can be manipulated to suit end user requirements. For example an SRF with a high plastic to biomass ratio would have a high net calorific value (NCV) of 15 – 20 MJ/kg which would be suitable for use in cement kilns. However, the yield of this material would be low at 20-30% of the feedstock mass with a corresponding high production of reject material (25 – 30%). Alternatively, the biodried material may be processed into a larger yield of lower NCV product where as much as 60% of the input feedstock may be delivered as an SRF with a CV in the range 10-15 MJ/kg (a similar range to RDF), and virtually no reject material generated. The reject material produced comprises mainly fines of partially degraded putrescible material which still retains a high biodegradability. This may be further processed by composting to produce a stabilised waste for landfill or with additional refining a CLO. Several MBTs of this design have been constructed in the UK using Ecodeco technology, e.g. at Frog Island and Jenkins Lane in East London treating residual waste from the East London Waste Authority. Additionally plants are under construction using Entsorga technology, e.g. in Westbury in Wiltshire.

3.5 MBT with rapid composting and recyclate production (RC+R)

This MBT configuration consists of a very rapid initial composting phase that reaches high temperatures up to 80^{o}C for as short as 6 days in a reactor that mixes and churns the waste.
The combination of mechanical attrition and rapid hot composting breaks the biodegradable matter down into a small particle sized fibre. This fibre is easily separated from the other waste components during subsequent mechanical processing which means that high recovery of metal and plastic recyclates is typically obtained. The high biomass fibre still has a high biodegradability and requires further composting if it were to be considered for recycling to land as a CLO. However it may also be considered as feedstock for AD or dried as biomass fuel. An example of this technology is the Civic Environmental Systems MBT at Thornley in County Durham.

3.6 MBT for biostabilisation (BS)

Here the whole waste is composted for an extended period of up to 12 weeks to remove as much of the biodegradability of the waste as possible prior to landfilling the whole residue. Stabilisation reduces the mass of waste and reduces the potential for fugitive CH_4 emissions from the landfill. Some recyclate recovery may be included especially of high value metals. A few processes designed around this MBT configuration have been planned, but with the increased cost of landfill due to the landfill tax increases, most MBT biostabilisation processes aim to have the flexibility to recover other products if suitable outlets are (or become) available.

For example the 400,000 tpa MBT under procurement by the Essex Waste Partnership (a group of local authorities near to London) is for a facility that can produce a stabilised waste for landfill in the short term (whilst SRF markets are still developing) but that has the flexibility to produce a high quality SRF in high yield if suitable outlets for the solid fuel can be found. Another example of this type of facility is the MBT at Waterbeach Cambridge which uses Komptech mechanical sorting technology and Kelag composting technology.

4. MBT OUTPUTS

A key element of MBT technologies being successful is the ultimate use of the products and outputs. The following section highlights the key outputs and issues of concern which surround their use.

4.1 RDF and SRF

Designation of the solid fuel product as a SRF rather than a RDF is beneficial as the SRF is considered in the UK as a more stable and tradable commodity (especially for export). Various European Committee for Standardization (CEN) standards, (e.g. EN 15359 Solid Recovered Fuels – Specifications and classes, EN 15358 Solid Recovered Fuels – Quality management systems), have been developed to analyse, categorise and ensure the quality of the SRF. As a minimum to be classed as SRF in the UK the SRF must be categorised according to EN15359, have a particle size of no greater than 150 mm and a residual biodegradability as measured by the real dynamic respiration test (EN15415) of no greater than 1500 mg O/kg LOI.h.

SRF is seen (due to its quality assurance) as being a solid fuel that may be applied in a wide range of energy based systems. These may include small scale systems such as school heating, specific industries such as a fuel for cement kilns, feedstock for gasification and pyrolysis facilities, and as a general fuel for EfW plants. It is often considered in Scandinavian countries as a stable solid fuel (low self-heating potential) that may be stockpiled during summer months and used in winter when demand for energy is higher

RDF is typically a less defined solid fuel than SRF and is seen as being used only in EfW directly. This is acceptable if the RDF outlet is available and has been fully considered as part of the MBT procurement process and subsequent decision. As RDF may be wetter and less defined than SRF its uses may be fewer and it is unwise to store this material as it may retain significant microbial activity and have the potential to self-heat leading to self-combustion risks.
In the UK most MBT facilities producing an RDF would aim to have this transported off-site and used in an EfW facility within 3 days of production. Within Europe operational EfW facilities that take SRF and other waste fuels are finding they have spare capacity as waste volumes reduce and segregation of recyclate and organics increase.

Consequently, there are changing flows of SRF between countries who have material for potential export and those who have spare EfW capacity. The trend is evident in the UK where SRF export for September 2010 to September 2011 reached one million tonnes, up from just 67,000 tonnes the previous year, with the primary destinations being Denmark, Estonia, Germany, Netherlands, Portugal, Spain and Sweden (letsrecycle.com, 2011). Additionally, Environment Agency data shows that the list of companies permitted to export SRF has increased (letsrecycle.com, 2011). Having a guaranteed output for the fuel produced is essential for the delivery of a successful project, particularly given the rising costs of landfill. Therefore, choosing the fuel outlet first will dictate the fuel required and as such the type of MBT technology required to produce the fuel. If planning to export, then SRF will be required, whilst a dedicated RDF plant can operate on a less refined fuel such as RDF.

4.2 MBT with AD for biogas

Recent legislative and policy (fiscal incentives) initiatives are promoting the AD of putrescible wastes in the UK, especially of separately collected municipal food wastes, which has stimulated the development of new dedicated AD facilities (Defra 2011b, WRAP 2012). This promotion of AD has started to influence the selection of MBT designs with many facilities now being developed which incorporate an AD biological treatment step for the putrescible fraction of the residual MSW (mainly food waste). However, in our involvement in the procurement of AD facilities in the UK, two issues have come to our attention that require careful consideration.

Firstly, AD is a complex biological process involving consortia of many micro-organisms operating in balance and consequently requires a relatively consistent feedstock and is not tolerant of perturbations. In an MBT with AD facility the feedstock for the AD process is derived from the food and green garden waste in the mixed residual MSW. The composition of MSW is variable and likely to change over the typical 25 year lifetime of an MBT facility. Ricardo-AEA has known of a case where the residual MSW feedstock composition had changed so much between design and construction that insufficient putrescible material would be available for the designed AD capacity before operation began. To allow for this risk the size of the AD facility is often reduced to accommodate a lower feedstock tonnage than is potentially available in the MSW waste stream. Whilst this ensures the AD will always have a sufficient feedstock supply it means the energy recovery is limited and that there is also then a volume of digestate and a volume of excess untreated putrescible waste remaining. Designs then typically incorporate a composting stage to manage this combined biodegradable output prior to landfilling.

Secondly, the disposal of any digestate is problematic. Whilst it is a CLO which can potentially be recycled to land, it is still classed as a waste under EU regulations and requires an Environmental Permit for this use (see details below). Alternative uses for the digestate could be as a high biomass containing solid fuel which would attract fiscal incentives as a renewable energy source. However, digestate typically produced with a 70% moisture content and accounting for about 25% of the input feedstock tonnage, would need to be dried to about 30% moisture content for use as a solid fuel.

In a typical AD facility there is sufficient waste heat from biogas combustion to dry about a third of the digestate. Hence such a route would entail significant additional energy consumption and cost, thus reducing the benefit of having the AD facility in the first place.

In the authors' view MBT with AD is not a perfect technological match and has downsides that need to be better understood before many ill-conceived facilities are constructed in the UK. This is a good example of where the impact of Government policy may not have been thoroughly thought through or is not having the desired impacts downstream.

4.3 MBT for recycling

The UK has set high targets for recycling and is moving towards these through the introduction of at source separate collections or by co-mingled collections of glass, metals, paper and plastics which are then processed in material recovery facilities (MRFs) into separated recyclables. The UK is introducing Quality Protocols (QP) and Publicly Available Specifications (PAS) for such materials so that recovered materials that have been produced by such QPs and meet the PAS criteria attain end-of-waste status (EA 2012). This means that they will be considered as products and regulation of their use will be less stringent.

The introduction of voluntary separate collections at the kerbside for households is however never 100% effective and significant amounts of potentially recyclable material will still be present in the residual MSW. As discussed previously, all MBT facilities aim to recover valuable metals, and many may also aim to recover other recyclables such as plastic and glass (as aggregates) and possibly paper. At best an MBT plant is able to recover about 15 – 20% of the input waste as recyclables. Any LA aiming to maximise its recycling rate may attempt to utilise the MBT asset for improving its overall recycling performance. Those LAs that have chosen MBT for the treatment of their residual waste over traditional combustion facilities have the potential benefit of being able to recover combustible plastics and paper as well as metals and aggregates from their residual waste.

However, one of the main issues with the recyclables derived from mixed wastes, particularly those that have gone through an MBT facility, is that their quality is generally much poorer than from separate collection schemes as contamination from other waste components is difficult to avoid. In 2011, about 9,474,000 tonnes of recyclates were collected by UK LAs of which 1.94% was rejected by recyclers due to contamination (MRW 2011).

The amount of this rejected material from MBT systems was not reported, but industry concerns believe recyclate from MBT systems will always be the first to lose their end markets due to their inherent poorer quality. Given the scrutiny on the quality of recyclables that are exported, a market downturn could leave the poorer quality recyclates from MBT in a vulnerable position. This is a risk element that needs to be mitigated in how any MBT is designed, procured and managed.

4.4 Compost like outputs (CLO)

Many MBT facilities could produce significant amounts of CLO as an output, either as digestate and/or compost from refining the outputs from the biological steps. Composts and digestates contain nutrients N, P, and K and can be used as fertilisers, and the organic matter when applied to soil can improve soil quality as a soil conditioner. Composts and digestates derived from source segregated materials that are produced according to QPs for compost and digestate (WRAP 2012) and comply with their respective specifications (PAS100 and PAS110) attain end-of waste status and may be applied to land under Environmental Permitting Exemptions. However because MBT derived CLOs are from a mixed waste which may contain some hazardous materials this type of CLO does not comply with these QPs and PAS specifications. It is therefore classed as a waste and as such its application to land is regulated under waste regulations. It can still be applied to land under an Environmental Permit but the conditions for its use are far more stringent. This increased regulatory stringency has inhibited the uptake of MBT systems specifically producing CLO as a means of diverting biodegradable organic waste from landfill.

How all the digestates produced from all the planned MBT with AD facilities are to be managed is an interesting question in light of this regulatory position.
This seems an area that does not receive much attention until the fine details of MBT designs are exposed during the procurement. However, this is a topic that is now under closer scrutiny by the UK Government and their Agencies – in particular WRAP and the EA.

5. RESIDUAL WASTE COMPOSITION CHANGES

The discussions above have hinted that MBT designs are very sensitive to the waste composition feedstock. Residual household waste is a mixture of many components, which can be broadly categorised into materials such as paper and card, metals, plastics, non-combustibles, garden waste, kitchen (food) waste, textiles, hazardous household waste, waste electrical and electronic equipment (WEEE) and fines. However, each of these broad categories may be sub-divided further into a greater level of definition.

For example, paper and card might be further sub-divided into newspaper, magazines, directories, corrugated cardboard, other card, recyclable paper and non-recyclable paper. Most studies of mixed household waste composition might categorise the waste into over 50 different components. Future developments to minimise waste, recycle more, and the substitution of materials in manufacture is likely to mean that the detailed composition of residual waste will change over the 25 year lifetime of an MBT facility. With a combustion EfW facility the fine detail of the residual waste is of little concern as long as it remains combustible with a reasonable NCV. An MBT facility however, is based on several mechanical and biological processes. As each waste component will have different properties such as size, density, chemical constituents, malleability, and biodegradability they will behave differently in each process. Whilst each processing unit will be able to accommodate some variation in its feedstock composition there are limitations and the MBT design is focused on the expected waste composition. To accommodate any change in waste composition would entail significant and costly over-design in the facility.

In MBT procurement it is the authors' experience that lengthy dialogue occurs during procurement between the client and the preferred contractor regarding the range of input waste composition that the MBT can process with guarantees of performance and the consequences if the waste composition falls outside these ranges. MBT is often seen as flexible but it is not without limitations that must be fully understood at the design and procurement stages.

6. CONCLUSIONS

Mechanical Biological Treatment of residual MSW is an alternative treatment technology to incineration with energy production that will account for a significant fraction of UK residual waste treatment in the near future. It is often preferred to incineration on the basis of being more acceptable to the local residents. It however, has some limitations such as its reliance on a consistent feedstock composition, its production of relatively poor quality recyclates and its reliance on other treatment facilities if producing fuel.

MBT designs and performance vary considerably, with numerous styles of facility and technology provider available in Europe. In terms of a long term residual waste treatment procurement process, there are a number of factors that need to be fully considered during the selection of a specific MBT design for any particular application to ensure it is the best solution for the situation in question.

Clearly MBT is a viable solution, but it is not the only option available, something that for a while the UK decision-makers were being led to believe. There remains a great deal of hype surrounding MBT facilities, but with increasing numbers of sites, operating hours and informed client designs the 'greenwash' surrounding MBT is being replaced with hard based evidence.

As such, MBT is a solution that is here to stay for European waste management purposes, allowing the treatment of residual waste management and the production to varying degrees of fuels, recyclables, stabilised wastes and compost like products, which should meet market demands in the short term, although longer term market demands are less certain.

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