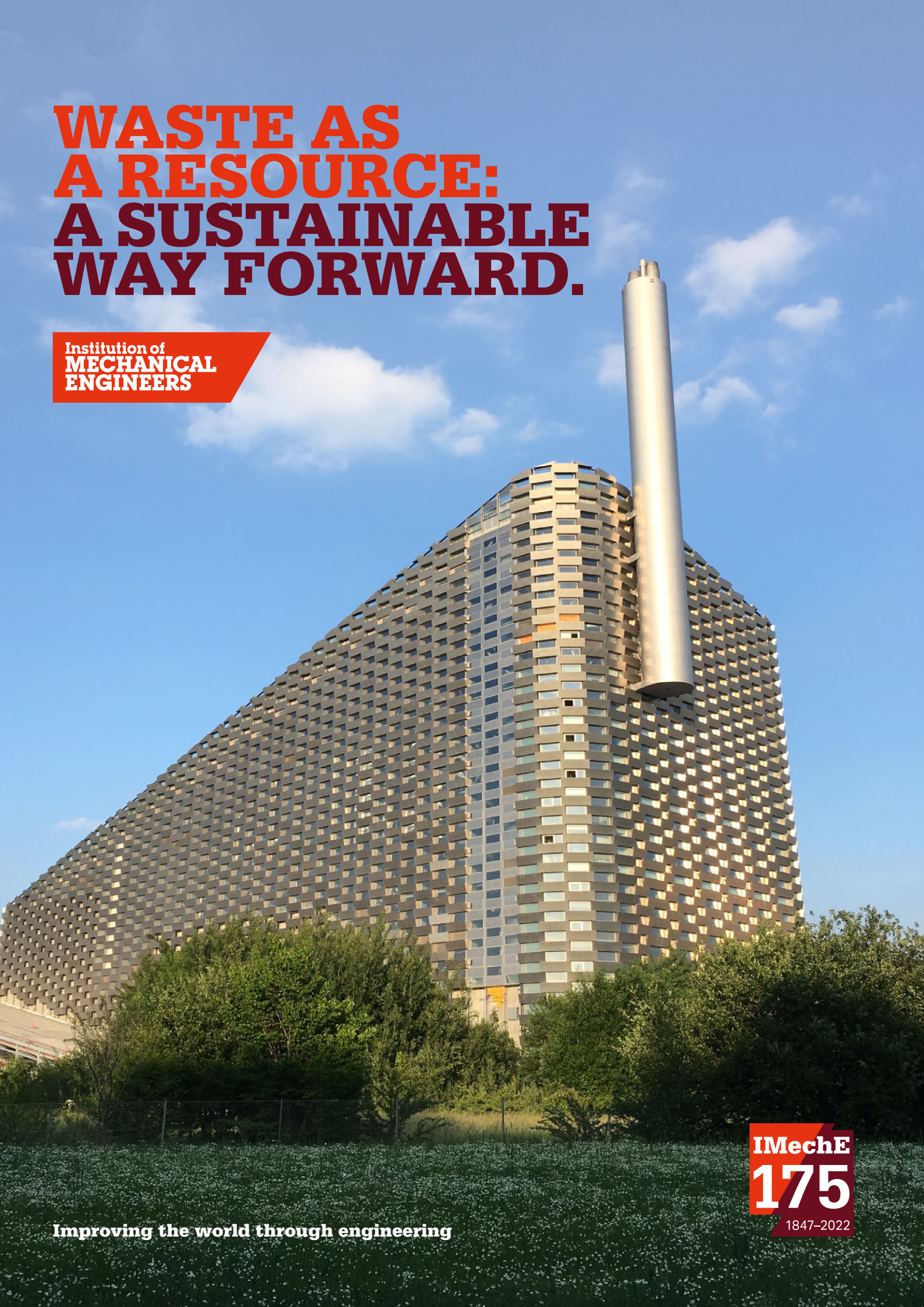
WASTE AS A RESOURCE: A SUSTAINABLE WAY FORWARD.

Institution of MECHANICAL ENGINEERS



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We need to stop seeing waste as a problem and to start seeing it as a valuable resource and use it to maximum advantage.

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Contents

Executive summary

The original Institution document with the title Waste as a Resource was first published in 2009[1], as a follow-up policy statement to the Institution's report, Energy From Waste: A Wasted Opportunity[2] of the previous year. Had the principles of these two documents been followed over the intervening decade, UK waste, energy and emissions policies could have been much more effective, binding targets could have been met and the UK could now have a more clearly-defined and sustainable future ahead as it faces highly ambitious Net Zero emissions targets for 2050. For these reasons, we are updating and republishing the Waste as Resource policy statement. The issues addressed are as relevant today as they were then.

The 2009 policy statement claimed that the commonly accepted Waste Hierarchy was not working and was becoming a significant hindrance in achieving the UK Government's legally binding commitments for 2020 on emissions and energy. Unfortunately, the Hierarchy viewed and still views waste as a problem rather than as a resource and thus does not deliver the climate change mitigation (CCM) for which it was designed. The alternative approach was the concept of 'Waste as a Resource' (WaR). Given its potential to combat both climate change and the continuing increase in waste arisings in the UK, the Institution of Mechanical Engineers urged the Government and does so again, a decade or so later, to change its position and review the Waste Hierarchy in the context of a WaR approach.

The Waste Hierarchy (see **Figure 1**) was adopted in the 1990s by the UK Government as a tool to assist decision-making in waste management with a view to environmental responsibility and the combatting of climate change through mitigation. Many versions of the Waste Hierarchy exist (often with additions and amendments which can be very misleading) but we have reverted to the basic '5-Rs' diagram for simplicity. Despite its frequent re-statement, however, use of the tool in practice has shown that it is inadequate and not fit-for-purpose. The problem mainly lies with the way in which the Waste Hierarchy has been implemented, ie:

- It has not encouraged the necessary levels of waste Reduction (1st tier); reductions claimed are often the result of redefinition of 'waste', rather than genuine prevention or reduction.
- Re-Use (2nd tier) has not been widely practised in the UK and is unlikely to increase in a developed, 'throwaway' society where it is very much cheaper to replace with brand new imported products than to repair, refurbish or renovate.
- Recycling (and composting) (3rd tier) has been the mistaken focus of UK Government policy in recent years; recycling targets are not well-designed to achieve true CCM. Market demand for recyclate is variable, leading to large stockpiles of unused recyclable materials.
- Energy recovery (4th tier) has been confused with incineration by both Government and NGOs; because of their objections to perceived incineration, energy recovery has been seen as the least desirable solution.
- Rejection of waste (5th tier), ie by landfilling, continues in large volumes and the various plans to phase out landfills have been abandoned. Indeed, in September 2019, the Scottish Government had to defer its 2021 landfill ban to 2025 and may struggle to meet that.[3]

The Institution of Mechanical Engineers recommends the Government:

- **Replace the Waste Hierarchy** to drive prevention of waste at source, climate change mitigation and the recovery of energy and materials – valuable resources which will reduce imports and boost the UK's economy. The primary premise of its replacement must acknowledge that reducing or preventing waste of all types is paramount. Not producing the waste in the first place has by far the most beneficial effect on the environment.
- **Deal effectively with all waste streams.** Rather than the almost exclusive focus on the small proportion of total waste arisings which are 'household' waste, develop more effective strategies for dealing with commercial, industrial, construction, demolition and agricultural waste.
- **Adopt a long-term zero-to-landfill approach** and publish independently audited, transparent data on the recovery and destination markets of all materials and energy (heat, transport and electricity).

Figure 1: The 5 Rs of the conventional Waste Hierarchy

Figure 2: The 4 Rs – A proposed simplified Waste Hierarchy

Background

Traditionally, our waste had been either buried (landfill) or burnt (incineration). However, neither method ultimately disposed of all waste items and both can have serious negative impact on the environment. In more recent years, waste has been dealt with in a more environmentally-responsible way; the last municipal waste incinerator in the UK closed in the mid-1990s and most landfill sites have now been equipped with landfill-gas (LFG) recovery to remove some of the environmental dangers associated with LFG (mainly methane, carbon dioxide but also trace gases that may be toxic). However, these measures still treat waste as a problem and ignore the potential of various waste-streams as a valuable resource for the future.

During the 1990s, concern developed about the way we handled waste in the UK. A perception that other European countries dealt with their waste far more effectively, resulted in the concept of the Waste Hierarchy being born. Developed and refined over the years, this thinking was formalised by Defra in Waste Strategy 2000.[4]

Since the late 1990s, legislation concerning waste has been required to take climate change mitigation (CCM) into account. However, it has never been clear how the Waste Hierarchy achieves this. The Institution of Mechanical Engineers maintains that, while it completely accepts the vital importance of CCM, any competent waste strategy must also consider rises in global population and energy consumption expected by 2050, as well as the proposed phasing out of all types of fossil fuel combustion (for which, as yet, there are not always clear alternatives).

The Waste Hierarchy's limitations

1st Tier – Reduce

Although originally developed as a useful tool to help to prioritise waste management, the Waste Hierarchy has become a key component of the Government's waste management strategy that is enshrined in UK law, despite its practical shortcomings. As **Figure 1** demonstrates, the primary objective of the Waste Hierarchy is to reduce or prevent waste. However, Defra's 2019 statistics show that figures for what is now called 'Waste from Households' (WfH) in 2010 and 2017 were unchanged at c.27 Mt/y; whilst 'Commercial & Industrial' (C&I) waste only very slightly reduced from 43.7 Mt/y in 2010 to 41.1 Mt/y in 2016, although this may well reflect the continuing demise of the UK's Industrial sector rather than genuine waste reduction.

2nd Tier – Re-use

Similarly, Re-use has never been a practical proposition in a developed society, other than, for instance, in car-boot sales, or more recently by internet-based used object trading or exchange platforms such as eBay or GumTree, all of which are admirable but are neither recorded in Government statistics nor regulated by Government. Unless and until it becomes cheaper and/or legislation is put in place to repair and/or refurbish items than to buy new, many people will opt for the more up-to-date product and throw away the old one. This is normal human behaviour. It is clearly very difficult to measure and hence promote activity in this category.

3rd Tier – Recycle

The Waste Hierarchy has therefore failed to deliver on its two primary objectives: Reduce and Re-use. This may be why the UK Government and Local Authorities have tended to focus on the third tier: Recycle. However, it is not clear what real environmental benefits widespread recycling achieves, especially if whole life-cycle analaysis (LCA) is used. The original thinking was that making new products from waste rather than from virgin materials was invariably more environmentally friendly. While this is understandable as a superficial view, it is overly-simplistic on a number of grounds (**see page 07**).

Recycling realities

Whilst widespread recycling is commendable in principle, it is not always environmentally sound and other waste management approaches should also be considered. For example:

- There is no universally agreed definition of the word 'recycle'. Originally meaning: 'to turn into a different product', today it is generally used to mean 'source separation' or even "reuse". Local authorities seem to use it to mean 'passed through a Materials Recycling Facility (MRF)', regardless of the ultimate destination of that waste (genuine recycling, EfW, landfill). Without a clear and agreed definition, 'recycling targets' become both meaningless and misleading.
- If the private sector is to be responsible for recycling, there must be a commercial market for the recyclate or recycled products. Events over the past decade have shown that this is not always the case and has led to the stockpiling of UK-generated recyclate and even worse, to the exporting of unrecycled UK waste to China and SE Asia, without any knowledge of whether it will actually be recycled, burnt, landfilled or become ocean pollution. This problem became so acute that since December 2017 the Chinese Government has refused to accept most wastes from the UK, leading to a crisis in the waste management industry (for the ethical implications of this, **see page 11**).
- Virtually any genuine form of recycling requires large amounts of additional energy (heat, transport and electricity), most of which will currently be sourced from fossil fuels, exacerbating (not reducing) the greenhouse gas (GHG) emissions problem. Indeed, one of the attractions of exporting (or 'offshoring') un-recycled waste to developing countries is that the substantial energy and GHG emissions costs have to be accounted for in the importing country, not in the country which created the waste.
- Proponents of recycling often claim that GHG emissions from the process are lower than those from the manufacturing of products from virgin materials. This may have some merit if the recycling and manufacturing processes take place and are accounted for in the same country, but this rarely applies to any great degree in the UK where both the processing of recyclate and manufacturing of products occur largely overseas, in places where the emissions associated with energy use and transport may often not be correctly recorded.
- Even genuine Recycling, as practised in the UK, should generally be described as 'down-cycling', as the resultant product is often of a lower quality grade than the original. Furthermore, materials may go through one recycling, or even two, but the material is constantly degrading. Although this might be practically acceptable, neither of these features are consistent with the 'Circular Economy', see below, which envisages the 'up-cycling' of materials. Up-cycling of some waste items is technically possible but is generally costly in terms of both energy and labour and the commercial market for such items is currently limited.

4th Tier – Recover

The fourth tier, Recover, usually taken to mean 'energy recovery', has generally been regarded by Governments and NGOs as less desirable than recycling. This is possibly due to a general misunderstanding of the crucial importance of energy to our modern way of life. It is important to stress here that a typical modern Energy from Waste (EfW) plant is not remotely an 'incinerator with energy recovery' but a sophisticated technology which converts a relatively sustainable fuel – usually refuse-derived fuel (RDF) – into useful energy in the form of heat, electricity and sometimes fuel for transport.

RDF is defined as 'material that is produced from waste, has undergone some sort of treatment process, and is intended for use as a fuel'.[5] The EfW industry specifies and sets standards for RDF, based on calorific value (CV), moisture content and chlorine levels in the fuel (typically CV >14 MJ/kg, moisture content <20%, chlorine level <1%), to ensure it meets legal emissions requirements such as the Waste Incineration Directive (WID). Some UK EfW plants accept RDF with CV as low as 8 MJ/kg but this is not ideal and is permitted only as an expedient. It is important to note that an EfW plant is not a 'waste treatment plant'; any necessary treatment usually takes place before the RDF arrives at the plant.

By far the largest proportion of energy demand in the UK is in the form of heat (40% in the UK as a whole, >50% in Scotland alone).[6] A direct-combustion EfW plant is inherently a Combined Heat and Power (CHP) plant, which is capable of delivering much larger quantities of heat than electrical energy. In sharp contrast to most other northern European countries, the UK has chosen to build EfW plants which supply only electricity, while the co-generated heat is wasted to the atmosphere; the thermal efficiency of such plants is c.25%.

In Denmark, for example, the co-generated heat energy, if not used in industrial processes, is legally required to be supplied to the nation's district heating network and used to heat buildings. The overall thermal efficiency of such a Danish CHP plant is >90% and there is a much-reduced need (avoided cost and emissions) for fossil fuels. The consequent positive impact on climate change is obvious.

5th Tier – Reject

The other original major objective of the Waste Hierarchy was to reduce the amount of material going to landfill, ie genuinely 'wasted', to negligible proportions in the shortest possible time. This has proved difficult to achieve in the UK because the methodology has been to achieve the goal by Government edict and taxation, rather than by a clear 'zero-to-landfill' strategy. Consequently, although the amount of material going to landfill has certainly reduced over the past decade, it is still very much higher than is the case in countries such as Germany, Benelux and Scandinavia, see Eurostats.[7]

The circular economy

The original concept of the 'Circular Economy' was first proposed by Braungart & McDonough in their book 'Cradle to Cradle – Re-making the Way We Make Things'.[8] It also suggested that the 'reduce – reuse – recycle' methodology merely perpetuates a cradle-to-grave philosophy. The central idea was that the 'circular economy' could move the world from using 'waste' as a noun to using 'waste' as a verb. It proposes a world where all materials are regarded as precious and the concept of deliberately wasting materials is eradicated by design (an engineering principle, for example: 'design for re-use' or 'design for disassembly') – everything has a use. This is not the same as a concept such as 'zero waste' which largely describes a political ambition – it lacks a coherent strategy and relies on re-naming and manipulation (not design) to be effective.

However, the concept of a 'circular economy' as currently proposed has flaws. There is an underlying assumption that adequate quantities of sustainable energy will be available in perpetuity, which is clearly not the case. Consequently, energy efficiency in supply and demand is not rated highly, which is contrary to the principles of the Energy Hierarchy.[9]

Regarding waste as a total resource is much more in line with the Circular Economy than the current practice of 'down-cycling' materials is. It also provides a relatively sustainable energy stream for the nation's future requirements. As we have seen, Danish practice regards EfW as a valuable resource, not as a problem. However, according to CEWEP 2019[10], people in Denmark 'recycle' more of their 'municipal' waste (c.52%) than we do in the UK (c.44%) but they use 48% of their waste as fuel/ feedstock in EfW plants, compared to just 41% in the UK (and this figure has increased hugely over the past five years). Similarly, the UK still sends around 15% of waste to landfill compared to just 1% in Denmark. Furthermore, as discussed elsewhere, the UK's 'recycling' figures are of dubious provenance.

Operation Green Fence

During the late 1990s and early 2000s, the ambition of the UK's Waste Hierarchy, and the Recycling tier in particular, was embraced by most Local Authorities (LAs) and materials such as paper, plastic, cans and garden waste for composting were deemed the 'low-hanging fruit' and easiest to collect. These materials were traditionally collected in the same container and taken to an in-house or contracted Materials Recycling Facility (MRF) operated by traditional waste management companies for processing into individual materials ready to sell on to the highest bidder.

Significant investment went into building and operating MRFs throughout the UK. The commercial aspects of the contract revolved around the Gate Fee and the rebate achieved for each of the recycled materials, while reducing costs and volume consigned to landfill. As the material was co-mingled, contamination, moisture and quality issues were an ongoing problem. Demand for such materials was initially supported by some UK/European end-users. However, due to the quality and contamination issues, the majority of the materials from MRFs was purchased by Chinese groups, which had a more tolerant view of the quality and moisture issues.

The advantages to the UK Government were clear: recyclate that had not yet been recycled could be claimed as 'recycled' in the published statistics; the (genuine) recycling facilities did not need to be built in the UK and the considerable associated costs could be avoided; the substantial energy and GHG emissions costs of recycling could be offshored to China and other Asian countries (a phenomenon sometimes referred to as 'carbon leakage'). The substantial energy and GHG emissions costs of shipping could be ignored, as vessels would have been returning empty to Asia anyway.

Understandably, China sent shock waves through the global recycling market in 2013 when it announced that, under its 'Operation Green Fence', it would no longer be accepting poorly sorted or dirty shipments of recyclable waste from foreign exporters. Regardless, the UK (and other western countries) continued to ship large quantities of unrecycled waste to China, as before. Despite having provided substantial notice of its intentions, China still caused some consternation when, in 2018, it started to refuse imports of foreign waste and began returning containers to the point of origin. Since then, other countries, for example Malaysia, have also started to return waste to the UK, creating a real dilemma for a country which does not have sufficient recycling capability.

In January 2020, the UK Government belatedly announced a Bill banning or restricting the export of polluting plastic waste to developing countries. While this is encouraging, this ban should be at least extended to include paper waste. Had better domestic waste management and recycling policies been in place at the time, this whole saga could have been avoided.

Rethinking the Waste Hierarchy

As previously expressed, the existing Waste Hierarchy tends to see waste as a problem, not as a resource. The two main priorities of the Hierarchy, Reduce and Re-use, while laudable objectives, have been found difficult to achieve in an affluent, 'throwaway' society such as the UK. Consequently, almost all the focus over the past two decades has been on the 3rd tier of the Hierarchy (Recycle) and setting arbitrary 'recycling targets' that have not had clear definition and the practical grounding to be effective. This has resulted in the point of the Hierarchy being lost. Despite 'recycling' almost always being associated with materials and 'recovery' with energy, there is no obvious reason why energy cannot be 'recycled', or material 'recovered'; the distinction is, therefore, somewhat artificial.

Contrary to historically prevailing political outlooks, there is no one method of dealing sustainably with all waste streams and each needs to be separately evaluated as to whether it lends itself ideally to being converted into another material item or into energy for power, heat and transport; one should not be considered more important than the other. Both treat waste as a resource, so whether materials, energy, or both are recovered should depend on the relative suitability, see examples below, of the waste stream as well as on the commercial market for what is recovered.

Instead of relying on the present 'one size fits all' approach (loosely called 'recycling'), some waste streams (eg metals, PET bottles) should be given a 'material-prioritisation' strategy, while others (eg biodegradable materials) should be given an 'energy-prioritisation' strategy. Although 'source segregation' of waste remains a pre-requisite, it is important to emphasise the point that this is not recycling.

Recognising the artificial nature of the separation of 'recycling' and 'recovery', we propose a modification to the Waste Hierarchy (see **Figure 2**), which reduces it to four tiers. This leaves the first two tiers as the priorities they should be, removes the unhelpful competition between 'recycling' and 'recovery' and helps to focus attention on minimising the 'reject' tier, ie landfill. 'Zero to landfill' is an achievable objective (has already been almost achieved in several EU countries), whereas 'zero waste' is not realistic.

The solution to this dilemma must be to stop seeing waste as a problem and to start seeing it as a valuable resource and use it to maximum advantage.

Developing a waste as resource strategy

In the UK, demand for energy (and related energy cost) is currently most people's greatest concern – far more so than any perceived need for more sustainable materials. Despite this, the Government's waste strategy focuses far more on materials than it does on energy recovery. Whereas the UK manufacturing sector has substantially declined since its heyday, energy in all its forms (electricity, heat and transport) underpins modern society. In 2009, the UK Government legally committed us to meeting 15% of our total energy demand from renewable resources by 2020; this target was nominally split into 30% of electricity, 12% of heat and 10% of transport energy. It should be noted that the 15% overall commitment was itself well below the pan-EU 20% commitment, so other EU countries would have to make up the UK's shortfall.[11] In the event, none of these targets was reached by the end of 2020, except the sub-target for renewable electricity; indeed, if it were not for the electrical output from the UK's EfW plants, which Government statistics have always regarded as 'renewable', even this electricity target would have been missed.

Energy from Waste (EfW) is at the core of the WaR concept. A considerable number of EfW plants have been built in the UK over the past decade, which is a major improvement over the position in 2008/9 and has gone part-way to help meet the 2020 targets. Furthermore, EfW provides the opportunity for 'synchronous' electrical generation, to help deal with the system challenges of intermittency of certain renewables, particularly wind and solar.

However, in the UK, almost all of the larger EfW plants have been designed as 'electricity-only' and the co-generated heat has continued to be wasted to the environment. A further problem is that the steam turbine condensers have tended to be air-cooled, rather than water-cooled, which means that even the plant's electrical output is considerably lower than it would otherwise have been and hot air is simply wasted to the atmosphere, which is detrimental to the environment. Although a step forward, plants built with these constraints do not fulfil the potential of WaR.

As noted above, most EfW plants also produce large quantities of heat energy, which have the potential for far higher climate change mitigation than 'electricity-only' plants. By using this co-generated heat to supply industrial processes and/or district heating systems, a far greater maximisation of the energy potential of the resource becomes available and fulfils the WaR criteria. Given the current massive and unprecedented increases in the cost of all types of energy supply, which is resulting in many more people in the UK falling into fuel poverty, this source of low-cost, dispatchable energy could have a significantly beneficial impact on the UK, whereas a focus solely on 'recycling' will require the consumption of ever more scarce and expensive energy supply from other less sustainable sources.

IMechE continues to support the genuine recycling of materials, if that is the best environmental solution but with more attention to be given to the setting of recycling targets that have a clear basis and defined practical pathways. It is important that constraints on material resource and constraints on energy be considered in conjunction with each other to arrive at the optimum environmental outcome. This may be viewed as a coordinated application of the Waste Hierarchy and Energy Hierarchy.

A resource is a resource. The Waste Hierarchy must be re-assessed and adapted to reflect real circumstances and allow those designing waste management strategies to implement effective solutions.

Recommendations

1. **Replace the Waste Hierarchy** with a model that genuinely delivers on the prevention of waste. The existing Waste Hierarchy has outlived its usefulness and there needs to be a considerable reassessment of the way we view and deal with waste throughout the UK. The primary premise of its replacement must acknowledge that reducing or preventing waste of all types is paramount. Not producing the waste in the first place has by far the most beneficial effect on the environment.
2. **Release the value of our resources.** Where 'waste' is inevitable and products not practically reusable, careful consideration must be given to achieve optimum use of all waste streams. Since waste is so diverse, it is obvious that there cannot be a single solution. Plants should be optimised so that some waste streams (eg metals, PET bottles) are given a 'material-prioritisation' strategy, while others (eg biodegradable materials) are given an 'energy-prioritisation' strategy.
3. **Adopt a zero-to-landfill approach.** For many reasons (eg lack of new sites, the European Landfill Directive, environmental hazards), landfill is no longer an acceptable way of dealing with waste. 'Zero-waste' is not a SMART (specific, measurable, achievable, realistic and timed) target, but a zero-to-landfill target is, and is much more likely to have greater impact. It is also essential to have transparent, independently audited, published data on the recovery and destination markets of materials and energy (heat, transport and electricity).
4. **A greater emphasis on all waste streams, not just household.** Legislators should not just focus on waste from households (currently only 12% of the total) and commercial and industrial waste (19%), but start developing effective strategies for construction, demolition and excavation (CD&E) waste (61%) and other wastes (8%).
5. **Use locally-produced waste to heat and power local communities.** There must be a far greater degree of community involvement; we envisage a scenario (already existing in other European countries) where a local community is responsible for its own waste and processes it into marketable products – electrical power, district heating and even transport fuel, as well as recovered materials. The positive climate change mitigation (CCM) impact would be enormous; the transport of waste would be avoided and the community would have complete ownership of the whole process.

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