Municipal Solid Waste and its Role in Sustainability

A Position Paper Prepared by IEA Bioenergy

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Introduction

Municipal Solid Waste (MSW) is primarily waste which is produced by the household, but also includes some commercial and industrial waste that is similar in nature to household waste and has been deposited in municipal landfill sites. MSW can be a liability if requiring disposal but also represents a considerable resource that can be beneficially recovered, e.g., by the recycling of materials such as aluminium cans, metals, glass, fibres, etc., or through recovery operations such as conversion to energy and composting. However, significant quantities of MSW continue to be disposed of in landfill largely due to its low cost and ready availability. In the European Union the landfill directive (1999/31/EC), as well as many national regulations, will reduce by 65% of the 1995 level, the amount of biodegradable materials going to landfill by 2016. Clearly, new waste management practices are needed.

In landfill the biodegradable components of MSW (e.g., paper and food wastes) decompose and emit methane – a greenhouse gas 23 times more potent than carbon dioxide (IPCC, 2001) and the cause of significant environmental problems. Other components (e.g., leachate) can also cause significant environmental pollution in air and ground water, and give rise to odour. In general, valuable resources are wasted. For these reasons most countries aim to reduce their dependence on the use of landfills for MSW. The EU countries in particular have set ambitious targets for reduction in the biodegradable component of MSW consigned to landfill and a consequent increase in MSW subjected to recycling and recovery operations. Some European countries, e.g., Sweden, Germany and the Netherlands, have already decided to ban the biodegradable fraction from landfills in the coming years. In state-of-the-art landfills the gas is extracted and used for energy purposes.

Many developed countries have adopted the principle of the waste hierarchy in order to guide their policies on MSW management. The hierarchy (Figure 1) lays out the preferred options for managing the waste from the point where it arises through to final disposal.

Cover Picture:
MSW District Heat Plant Spittelau, Vienna. Courtesy Fernwärme Wien, Vienna, Austria.

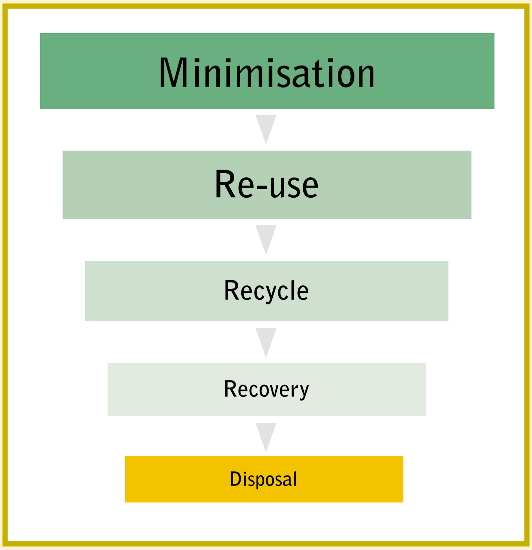

Figure 1: The Waste Hierarchy

Where it is economically viable, and environmentally sound, recycling of materials is preferable to treatment for energy recovery. In practice, however, even in countries with highly developed recycling infrastructure, significant tonnages of MSW remain after recycling to make energy recovery an environmentally justified and economically viable option – ahead of final disposal to landfill. Research, demonstration and dissemination are now focusing on the balance between waste minimisation, material recycling, energy recovery and landfill of the non-biodegradable fractions.

Whilst the composition of MSW can be highly variable, particularly between developed and developing nations, the removal of materials for recycling tends to leave a residue that has a significant calorific (heat) value making it suited to energy recovery operations. Typically, a tonne of MSW has about one-third of the calorific value of coal (8-12 MJ/kg as received for MSW and 25-30 MJ/kg for coal) and can give rise to about 600 kWh of electricity. Traditionally, mixed waste is incinerated in mass burning facilities; however, the trend with new installations is to higher efficiencies in power and Combined Heat and Power (CHP) production. Some countries have a minimum efficiency requirement. Recent legislation in the EU and Australia classifies only the renewable biomass fraction of MSW-based power production as renewable electricity.

MSW should thus be seen as a resource to be exploited rather than a waste requiring disposal.

Environmental Benefits and Impacts

As with all renewable energy technologies, the major benefit associated with energy recovery from MSW is a reduction of the gaseous pollutants that cause both local and global effects. Recently the IEA completed a comprehensive study of the positive and negative impacts of a range of renewable energy technologies. The study adopted a life-cycle-based approach so that emissions related to the manufacture of systems, their construction, operation and disposal were taken into account. The study found that, for conventional MSW energy recovery systems (e.g., mass burn), the total emission of CO_2 is 1100 kg per tonne of MSW and 1833 grams of CO_2 per kWh. Various assessments have shown that about 20-40% (depending strongly on the degree of separate collection of paper and organic waste) of the carbon in MSW is derived from fossil sources, e.g., plastics (see Figure 9). The remainder is derived from biomass and can be considered a renewable resource. Thus the non-renewable element of the emission is about 367 grams of CO_2 per kWh (i.e., 20% of the total emission of 1833 grams of CO_2 per kWh). In Figure 2 typical CO_2 emissions from MSW are compared with those from fossil fuel sources.

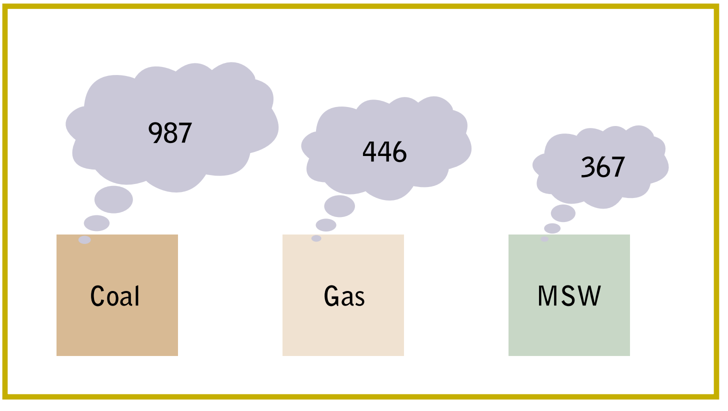

Figure 2: Life Cycle CO_2 emissions – grams per kWh of electricity

The CO_2 emission shown for MSW in Figure 2 does not take into account emissions that are avoided as a consequence of recovering energy from MSW. For example, if the MSW was consigned to landfill then about 70 kg of methane (actual range 50-100 kg) could be released for each tonne of waste. Given the higher global warming potential of methane, this is equivalent to 1610 kg CO_2 per tonne of MSW. In modern landfills about half of the methane can be extracted and utilised for energy production, therefore reducing the overall emissions. Further, the generation of energy from MSW avoids the emissions related to generating that energy from fossil sources. The recovery of energy from MSW can therefore lead to a net reduction in greenhouse gas emissions (see Figure 3). Thus, taking even the most pessimistic view, i.e., ignoring the benefits of avoiding landfill, energy recovery from MSW leads to significant savings of greenhouse gas emissions when compared to conventional generation of energy from fossil fuels.

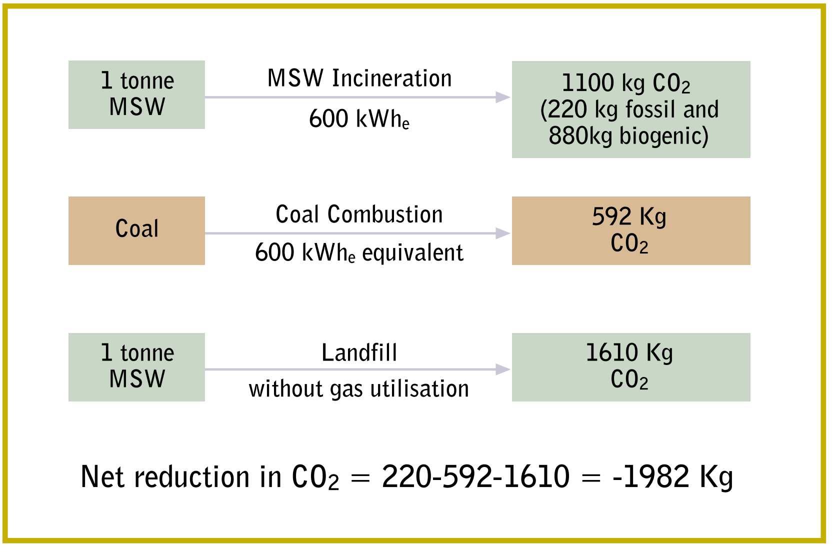

Figure 3: Greenhouse gas emissions from electricity production: MSW incineration compared to coal combustion and landfilling of MSW.
(kWh_e = kilowatt hour of electricity)

Other recent results of studies on the impact of solid waste treatment systems on greenhouse gas emissions are presented in Figure 4. In landfill, about half of the CH_4 is recovered (range of recovery rate 20-80%) and therefore some emissions still occur. If landfill gas is used in electricity generation, some equivalent CO_2 emissions can be avoided. With decreased landfilling of biodegradable materials the potential for energy recovery will be reduced. With mass incineration, no degradable organic material is deposited in landfill. Some materials with high-embedded energy, but zero calorific value (e.g., steel and glass) can be recovered before incineration and hence some CO_2 emissions can be avoided. It was assumed that the generated electricity replaces coal-condensing power, as with landfill, and the energy-related emissions are therefore negative even though quite significant amounts of CO_2 are emitted from incineration. In Solid Recovered Fuel (SRF) recovery, the landfill emissions are small due to the very small amount of disposed organic waste. Due to more efficient waste separation and subsequently recycling, more CO_2 emissions from steel and glass manufacturing can be avoided than with mass incineration. The largest effect on emissions is due to substitution of SRF for coal. With the SRF and paper fibre recovery, the effect on energy-related emissions is smaller than in the previous categories because a part of the combustible material (paper fibre) goes to material recycling. Although more paper manufacturing emissions are saved, the total effect is of the same magnitude as the SRF production case.

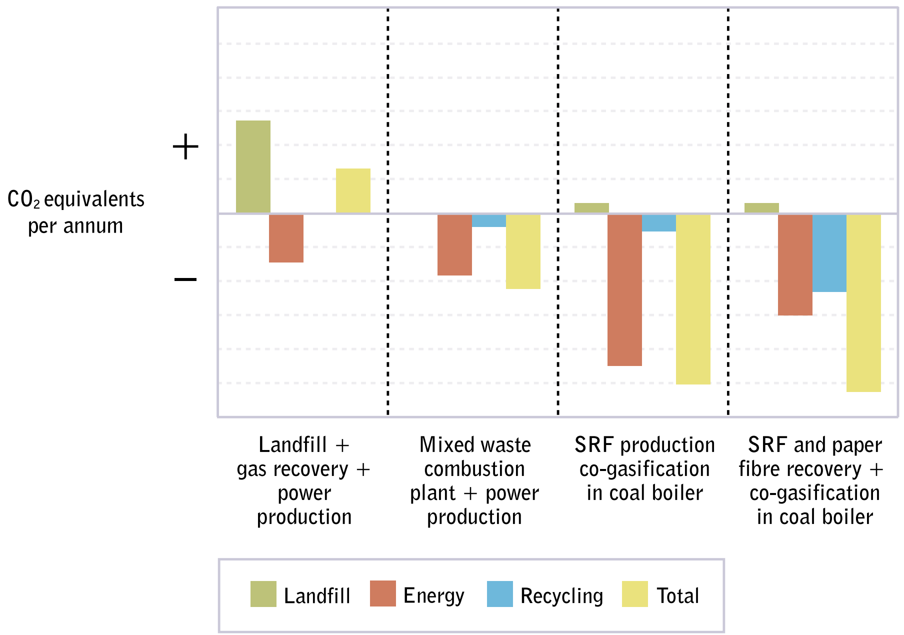

Figure 4: Greenhouse gas emissions of different waste management systems in coal substitution. An example from a city with one million inhabitants.

The substitution of energy from MSW for energy from coal, leads to significant savings in greenhouse gas emissions.

Even where the MSW is consigned to landfill there exists the possibility of utilising the generated landfill gas (rich in methane) for energy recovery, but the potential for substantial recovery will be reduced as the amount of biodegradable material is reduced. In addition, the recycling of secondary materials saves energy which otherwise would have been consumed for the manufacture of products from primary raw materials (e.g., compost *versus* chemical fertilisers).

Recovering energy from MSW also avoids all other potential impacts associated with the deposition of waste, e.g., leachates/groundwater contamination and longer-term pollutant liabilities. The deployment of any technology will have local environmental impacts and it is these rather than national or global environmental concerns which influence public acceptability and siting decisions. For MSW energy recovery, local impacts are associated with traffic movements, noise, visual intrusion, loss of amenity and local effects of pollutants. As with other technologies these impacts can be minimised if best practices in the design, siting and operation of plant are adopted.

The benefits of energy recovery from waste fuels are such that any state-of-the-art waste management policy should include energy recovery irrespective of the individual local strategic preferences (e.g., composting *versus* anaerobic digestion).

Drivers and Barriers

The utilisation of the biodegradable fraction of MSW as a bioenergy resource is intimately linked with the waste management policies that a country practises and with public perception. Energy recovery systems for MSW thus have to be integrated with other methods of treatment, recovery and disposal to avoid conflicting claims on the waste/fuel stream. Policies promoting the diversion of waste from landfill provide an opportunity for MSW energy recovery.

Public perception and hostility are currently critical barriers hindering the deployment of energy recovery systems for MSW in several countries. Selective reporting on emissions has contributed to negative perceptions. For example, reporting emissions from 30-year-old facilities but not from new ones that meet the most stringent modern emission standards.

IEA Bioenergy can play a significant role in removing misconceptions concerning MSW energy recovery by promoting information exchange and presentation of reliable data on emissions from state-of-the-art waste energy recovery facilities.

MSW conversion-to-energy, like *any other* fuel-to-energy process, will generate emission of pollutants. However, all state-of-the-art MSW conversion-to-energy technologies are certified to meet the most stringent emission standards, including those for dioxins, furans and other toxic pollutants.

The Role of Technology

The numerous conversion routes for MSW to energy are illustrated in Figure 5. Basically, these involve thermochemical processes (such as incineration, gasification and pyrolysis) and biological processes (such as anaerobic digestion). With the exception of mass burning or incineration systems, all other process routes utilise an upgraded fuel. This can be accomplished either by separation at source followed by simple mechanical treatment such as size reduction, or by extensive mechanical treatment of MSW to produce Solid Recovered Fuel (SRF).

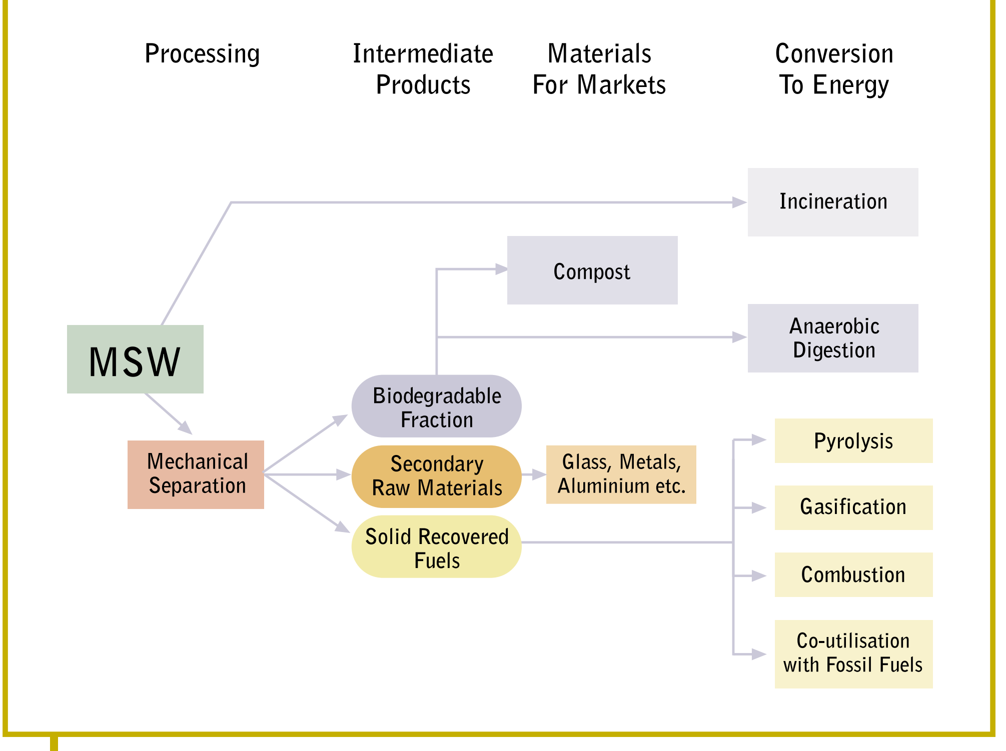

Figure 5: Pathways for MSW treatment for recovery and recycling processes

SRF is a solid fuel that in most cases has well-defined characteristics, properties and composition and can be traded as a fuel for energy generation. SRF presents significant opportunities as the main pollution sources have been removed during the mechanical pre-treatment process. It has a relatively high heating value and can be standardised as a commercial fuel. SRF can be co-utilised with several other solid fuels such as coal and/or biomass in co-combustion or co-firing processes. The European Commission has issued a mandate to CEN/TC 343 for the adoption of European standards for SRF so that such fuels could be traded in the energy market. Typical technical solutions are shown in Figure 6 below. These are in addition to commercial co-firing alternatives of wood fuels and coal.

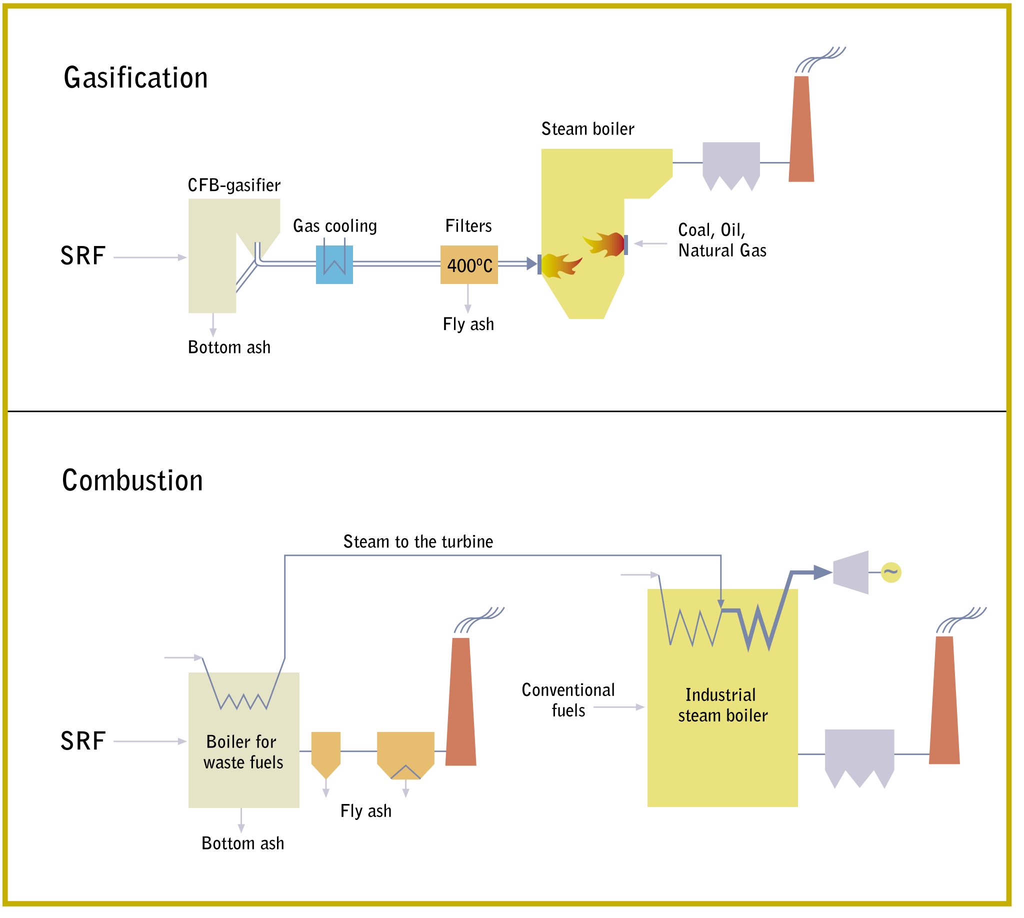

Figure 6: Typical co-utilisation applications of SRF

There are several state-of-the-art technologies for converting MSW to energy. Moreover Solid Recovered Fuel offers significant environmental and market opportunities, is relatively clean and can be traded in the market for numerous energy applications replacing fossil fuels.

A Renewable Source of Energy

By its very nature MSW is a heterogeneous substance composed of a range of materials. Figure 7 illustrates a typical composition for MSW in the United Kingdom – as could be expected from developed nations – and Figure 8 illustrates a typical composition of SRF. In Figure 9 the percentage of carbon that is derived from fossil sources (e.g., plastics) is compared with the amount of carbon from biomass sources. Thus it can be seen that about 80% of the carbon is biomass derived and considered to be from a renewable source. (Note: for Figures 7-9, the values depend strongly on the degree of separate collection of paper and organic waste).

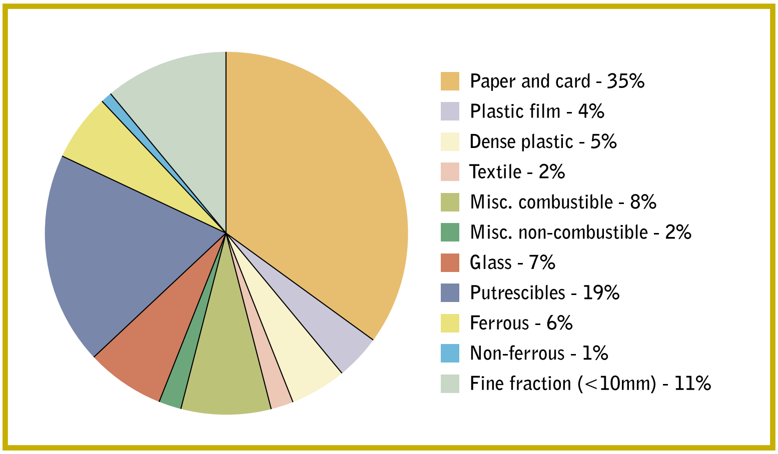

Figure 7: Indicative MSW Composition

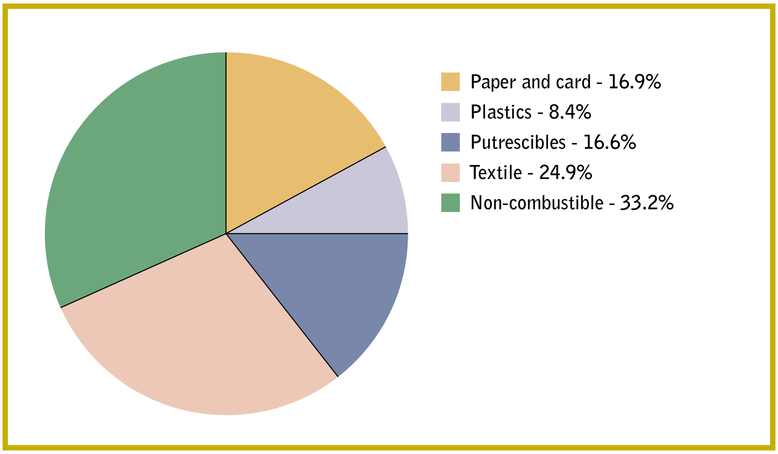

Figure 8: Solid Recovered Fuel Composition

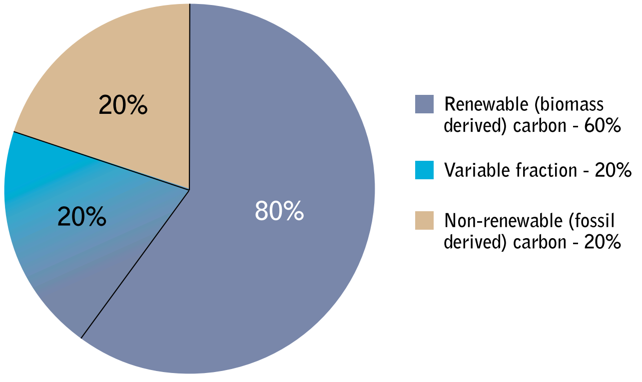

Figure 9: Carbon content of MSW (Wt%)

Up to 80% of the carbon content of MSW is biomass derived and therefore is renewable.

Contribution to Sustainable Energy

Life-cycle-based assessments of the major environmental impacts (or sustainability indicators) of MSW have shown the positive benefits to be gained from MSW energy recovery. These gains are in the form of:

- Reduced greenhouse gas emissions
- Reduced acid gas emissions
- Reduced depletion of natural resources (fossil fuels and materials)
- Reduced impact on water (leaching)
- Reduced land contamination

In the long term the potential for MSW energy supply is limited by the availability of raw material – there is a finite resource in each area. Nonetheless, reviews of the short- to medium-term potential for the range of renewable sources indicate that MSW energy recovery could be an important contributor to power generation. For example, the ATLAS study indicates that at present about 7% of energy produced from renewable sources in the EU is derived from MSW – making it the third largest contributor after large-scale hydro and use of biomass for heat. ATLAS also indicates the importance of the contribution from MSW into the future, with a similar ranking of market share in 2010. Energy recovery from MSW is therefore one of the major players in the early introduction of renewable energy.

MSW energy recovery has the potential to make a significant contribution to sustainable development

Conclusion

Energy recovery from MSW is already contributing to reducing global and local environmental impacts. The potential contribution and cost of deployment are such that it is likely to continue to make a contribution on a par with other renewable technologies currently entering the market place. Deployment of MSW energy recovery should be encouraged wherever it presents a viable and attractive way of integrating with recycling and re-use activities and minimising the impact of waste disposal.

Energy recovery from waste can reduce emissions of greenhouse gas and other gaseous, liquid and solid pollutants, has a great potential for assisting in meeting the Kyoto obligations, and can significantly contribute to sustainable development.

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Abbreviations

CHP	Combined Heat and Power
CH_4	Methane. A greenhouse gas 23 times more potent than CO_2
CO_2	Carbon dioxide
EC	European Community
EU	European Union
g	grams
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kg	kilograms
kWh	kilowatt hour
Kyoto	Kyoto Protocol - an international agreement aimed at reducing greenhouse gas emissions
MJ	Megajoules (10^6 Joules)
MSW	Municipal Solid Waste
SRF	Solid Recovered Fuel

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Energy from waste plant, Oxford, United Kingdom. Courtesy AEA Technology Environment, United Kingdom.

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