Greenhouse
gas abatement
Assessing WTE and landfill disposal

The pressing need to reduce greenhouse gas emissions places a considerable responsibility on those involved in the waste sector. Traditional methods of waste management such as landfilling are making a greater contribution to such emissions than alternatives such as waste-to-energy plant, according to a new study – and landfilling continues to be used, despite considerable developments in waste-to-energy technology in recent years. This article assesses the relative impacts of both methods of waste management from a greenhouse perspective, taking Australia as an example.

In line with their support for the Kyoto Protocol, a number of forward-looking countries have adopted strategies across a range of areas, including waste management, with the aim of reducing greenhouse gas (GHG) emissions. Methane is predominant among these emissions from the waste sector, as it is generated from the anaerobic decomposition of organic matter in landfills. In western Europe, where the drive for better environmental practices and technologies has generally preceded other countries, there has been a strong movement away from landfilling as a final disposal option towards recycling, and incineration with energy recovery and flue gas cleaning. In other countries, notably Australia, Britain and the United States, where there is still strong public antipathy to incineration, the debate on whether residual waste from the recycling of solid waste should be landfilled or incinerated still continues.

Given the urgency for measures to address the global warming problem effectively, this article examined the latest data and published studies to identify which of the cited technologies – landfill disposal, landfill disposal with methane recovery for flaring or energy recovery, or thermal recycling – is better in terms of reducing GHG emissions. It investigated incineration as a preferred option for mitigating the greenhouse impact of waste treatment, also looking in detail at Australian GHG emissions by way of example, and discussing other environmental aspects of the technologies.

In this article, ‘waste’ refers to non-hazardous solid waste that includes municipal solid waste as well as the degradable portion of commercial and industrial wastes and construction and demolition wastes; see reference 13.
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Landfill disposal

Landfill gas comprises approximately 50-60% methane (produced by anaerobic decomposition) and 40-50% carbon dioxide from the decomposition of organic materials deposited in landfills. This biogas is produced over a 20-30 year gassing lifetime. The Global Warming Potential (GWP) index of methane is taken as 21 times that of carbon dioxide on a 100-year time horizon. The GWP of a gas represents the relative warming effect of a unit mass of the gas when compared with the same mass of carbon dioxide over a specific period. The production of methane begins from about a year after the placement of waste and continues for over 25 years. In bioreactor landfills, methane development is deliberately enhanced to speed up methane production, and thereby stabilize the landfill in a shorter time. Unless this gas is recovered, flared and so converted to carbon dioxide, its global warming effect will be significant.

Landfill disposal with gas recovery

Landfill gas recovery with combustion of methane gas in a flare or for energy production, provides the means to mitigate emissions. Landfill gas extraction is, however, an inefficient means either to recover energy or reduce greenhouse emissions, compared to other, pre-burial energy recovery options. This is because only a portion of the methane is recoverable, and also because the gas continues to be generated at declining rates for years after practical exploitation has been discontinued.

Methane gas recovery from landfills still only achieves 40-75% during the lifetime of dedicated recovery facilities. Gases continue to diffuse, albeit at a lower level, for years after commercial recovery systems are discontinued, resulting in usually 50% or more loss of methane over the lifetime of the landfill.

Waste-to-energy plants

Methane emissions from waste incineration are negligible. As is the case for landfilled solid waste, the majority of CO₂ produced during incineration originates predominantly from waste from renewable sources, such as paper, wood or food remains, and its climatic relevance is therefore neutral. That portion of solid waste combusted from non-renewable sources should however be counted as GHG emissions resulting from human activity. Some authorities consider that solid waste contains approximately 75% biomass and 25% material sourced from fossil fuels, by weight. However, 50% of the calorific value of solid waste comes from the non-renewable sources (e.g. plastics), as these themselves have a higher calorific value. In assigning CO₂ for the incineration of solid waste (see below), the conservative figure of 67% biomass will be used in the calculation of GHG emissions.

WTE plants have seen a lengthy period of development with continuous improvements, especially to minimize pollutant emissions and improve the thermal efficiency of converting the energy inherent in the waste into power. The net efficiency of converting solid waste into grid electricity, using a modern WTE plant is approximately 22% after subtracting plant internal electricity consumption. The furnace and boiler design maximizes the conversion of thermal energy into steam, which drives the turbine that produces electricity. Technology companies are also prepared to give guarantees that less than 3% of combustible content (one company even guarantees less than 1%) remains in the bottom ash after incineration.

Treatment of solid waste through a waste-to-energy plant will avoid the methane emissions that would otherwise be generated by landfilling the waste. Non-renewable fossil fuels are also replaced in generating the electricity. The net effect is therefore a significant reduction in the emission of climate-threatening gases. On this basis, the UK Working Group on the Greenhouse Effect concluded that a substantial benefit could be obtained by the incineration of combustible, non-recyclable refuse and waste, in all possible cases with energy recovery. This is confirmed by findings which show that landfilling has the greatest greenhouse impact, although this can be mitigated somewhat by landfill gas recovery and combustion; waste treatment alternatives that include incineration were the most favourable when considering GHG emissions abatement.

Greenhouse gas emission abatement using waste-to-energy plants

To determine which of the main waste management options is best from the viewpoint of minimizing anthropogenic GHG emissions, calculations of these have been carried out for two common waste management options, landfill disposal of solid waste and waste-to-energy (WTE) thermal recycling. These use Australia as an example, looking at the full year to the end of June 1999. Calculations are based largely on the methodology used by the Australian Greenhouse Office (AGO), with modifications. In accordance with the AGO methodology, emissions of carbon dioxide and oxides of nitrogen from solid waste are excluded, except where they are derived from the incineration of part of the waste that contains fossils fuels or their products. In the case of landfilling, these gases are currently not included in aggregate emissions when expressed as CO₂-equivalent or CO₂-e.

Although for a Seghers reference WTE plant, oxides of nitrogen are known to be produced at the rate of 0.83 kg/tonne solid waste, the greenhouse potential of such emissions was not assessed, since these gases do not have Greenhouse Warming Potentials, and the AGO does not include these in national aggregate emissions. When expressed as CO₂-e, Nitrous oxides are also not estimated in the AGO methodology (or the present study) for landfilling or waste incineration, but are known anyway to be extremely low in emissions from a modern WTE plant.

The current approach taken is to consider what effect there will be on GHG emissions if the total solid waste currently landfilled in towns with a population greater than 100,000 is redirected to a modern WTE plant. Methane emissions from the solid waste are calculated as total emissions for the lifetime of the landfill gassing process. The waste generated by a town of population 100,000 is probably the minimum necessary for economic viability of a WTE plant.

This exercise shows that by processing the formerly landfilled waste through the WTE plant, only 5.2 million tonnes CO₂-e will be produced instead of the 14.0 million tonnes CO₂-e produced previously. Another 8.9 million tonnes CO₂-e of emissions will be avoided by the replacement of the fossil fuels needed to generate an equivalent amount of electricity in a WTE plant. The net benefit therefore in GHG abatement by using WTE plants to thermally recycle the previously landfilled waste is estimated to be a sizeable 17.7 million tonnes CO₂-e. This represents approximately 105% of the reduction in the current (1999) excess GHG emissions (16.7 million tonnes CO₂-e) above the level agreed under the Kyoto Protocol (see Table 1). This shows clearly that the WTE treatment for solid waste in towns with populations over 100,000 can be a very effective form of GHG abatement.

The ISVAG WIP plant in Antwerp, Belgium, with a generating capacity of 56 MW of heat and 13 MW electricity. Photo: Seghers
Some researchers have suggested that landfills have a role as a carbon sink. This is because certain elements of solid waste are only very slowly biodegradable (such as wood and leather) or, like plastics, are virtually non-biodegradable.24 On the other hand, suggest that landfills should not be considered as sinks in the calculation of greenhouse gas inventories, since they are in fact very bad from an environmental perspective. In the first place, the garbage is placed in an anoxic environment where approximately half the gas emitted from decomposition will be methane – a notorious greenhouse gas, which would not otherwise be generated if the material decomposed naturally on the surface, or was combusted. Although the IPCC (1995) guideline document for the decomposition of organic carbon in landfill is taken as 77%, part of the remaining organic carbon will continue to decompose over time to produce methane (GWP: 21). Any ‘sink’ benefits will be outweighed over time by the production of methane. 

Secondly, a considerable portion of the non-degradable fraction is plastics, which has a very high heating value (three times that of other biomass in the waste). If the plastic is locked away in a landfill rather than being recycled or incinerated, it is waste of a valuable, non-renewable fuel.

Landfill gas collection and combustion, with or without energy recovery.

A variation of the above exercise was carried out where, instead of treating part of the landfill waste through a WTE plant, a collection and combustion system was set up for methane generated from landfills in towns with a population over 100,000. It is assumed that the methane is flared and not used to generate electricity. In this case (Case 3), instead of an overall abatement of 77 million tonnes CO\textsubscript{2}e (compared with landfilling in Case 1) using WTE plants, only 63 million tonnes CO\textsubscript{2}e will be abated. The figure is based on indications that collection and combustion systems cannot normally avoid 50% loss of the methane. Therefore, the overall abatement of the excess GHG emissions can be achieved. It can therefore be concluded that with respect to climate protection targets, the efficient incineration of waste that cannot expediently be recycled offers major advantages over the conventional landfill approach. Significant environmental problems and GHG emissions remain from landfills, even if landfill gas is flared or used beneficially. For WTE technologies, however, improvements over the past 15 years have minimized pollutant emissions in flue gases, while treatments have facilitated beneficial uses for much of the residual incinerator ash.

The investigation has shown that if solid waste that is currently landfilled is instead processed through modern WTE incinerator plants, a major abatement of GHG emissions would follow. The magnitude of this reduction would, in the case of the Australian example for solid waste from towns of populations over 100,000, achieve 105% of the country’s current reduction, as compared to the Kyoto Protocol. Even with a doubling of the recycling rate in Australia resulting in a reduction of residual solid waste available for WTE processing, a significant 79% abatement of the excess GHG emissions can be achieved.

Closing off a landfill in Antwerp, Belgium. Photo: Seghers

### TABLE 1. Amount of above-Kyoto-target GHG emissions that various waste management scenarios can save

<table>
<thead>
<tr>
<th>Case</th>
<th>Amount saved (million tonnes CO\textsubscript{2}e) (%)</th>
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<td>3</td>
<td>12.3</td>
<td>79</td>
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Closing off a landfill in Antwerp, Belgium. Photo: Seghers

### References


Patel, M., von Thiene, N., Jochem, E. and Worrell, E. Further reading


