Materials or gases? How to capture carbon

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Executive summary

Municipalities seeking to minimise their contribution to climate change typically scrutinise various activities over which they bear direct responsibility. One such area is usually waste management. Municipalities may seek to reduce waste generation, and strive to increase recycling rates, recognising that these deliver the most significant benefits as regards greenhouse gas reduction. Materials that evade recycling are – typically – either landfilled or incinerated. When landfilling happens without pre-treatment, the principle concern centres around methane emissions and their impact on climate change in the short-term. In the case of incineration, the concerns relate to the greenhouse gases emitted during the combustion process.[1]

The European Union is increasingly likely to include incineration within the EU Emissions Trading Scheme in the near future. Consequently, questions arise as to how the operators of incineration facilities may respond. Although the potential exists for a range of different technologies and processes, this study compares two: the sorting of mixed waste leftover after separate collection (leftover mixed waste sorting, or LMWS); and the capture of carbon dioxide from incinerator flue gas for underground storage (carbon capture and storage, CCS). Key findings in this study focus onfacilities generating electricity only, with a main emphasis on a 200,000-tonne waste throughput facility. This scale aligns with the average size of EU facilities primarily dedicated to waste incineration. Cost models have also been developed for smaller (100kt) and larger (300kt) facilities.

The study assesses each of the two technologies in isolation (Incin + LMWS, and Incin + CCS), and also, in combination (Incin + LMWS + CCS), and compares them against the baseline where neither is deployed. The costs of the LMWS process are derived from previous work undertaken for ZWE. Estimated costs for CCS are based on literature review, incorporating both 'real-world' experience and modelling. One notable feature of the review of CCS costs is that the implied cost of capital (sometimes referred to as 'a discount rate') is often relatively low. While low costs of capital may be suitable for facilities heavily sponsored by the public sector in the short-term, as the technology becomes commercialised it might be reasonable to expect an increase in the weighted average cost of capital (WACC).

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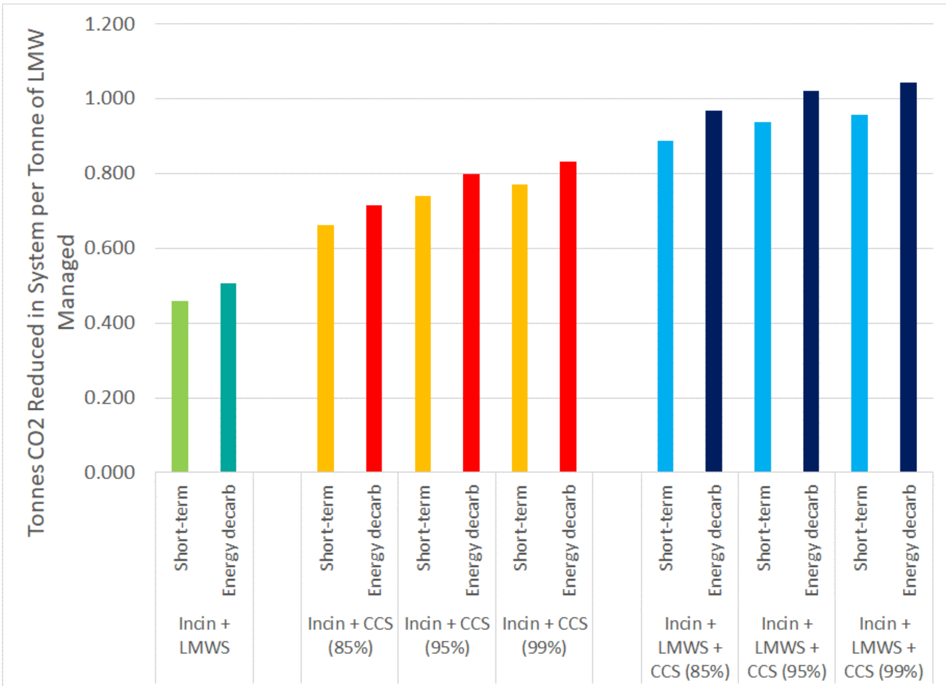
[1] In previous reports, we considered mechanical recycling and biological treatment (MRBT), which combines sorting of leftover mixed waste (in order to recover further recyclables from waste remaining after source separation) and biological stabilisation (for the biodegradable materials that were not captured by separate collection), with the remaining stabilised material landfilled at sites with suitable oxidation layers, to be a positive approach to management of leftover mixed waste. This was due to its environmental characteristics, and because it is more likely to retain flexibility in the waste management system to allow for continuous improvement in recycling (see Zero Waste Europe (2020) Building a bridge strategy for residual waste. Material Recovery and Biological Treatment to manage residual waste within a circular economy, Policy briefing, https://zerowasteeurope.eu/library/building-a-bridge-strategy-for-residual-waste/). The current report considers the relevance of mixed waste sorting in the context of incineration. It considers this in the context of ongoing discussions among policy makers, and within the waste management industry, regarding the potential application of carbon capture and storage (CCS) to incineration facilities. Because of the report's focus on the greenhouse gas impacts of different incineration configurations, it largely abstracts from matters such as the extent to which the application of the technologies concerned might increase, or diminish, the extent to which a waste management system is 'locked-in' to specific solutions.

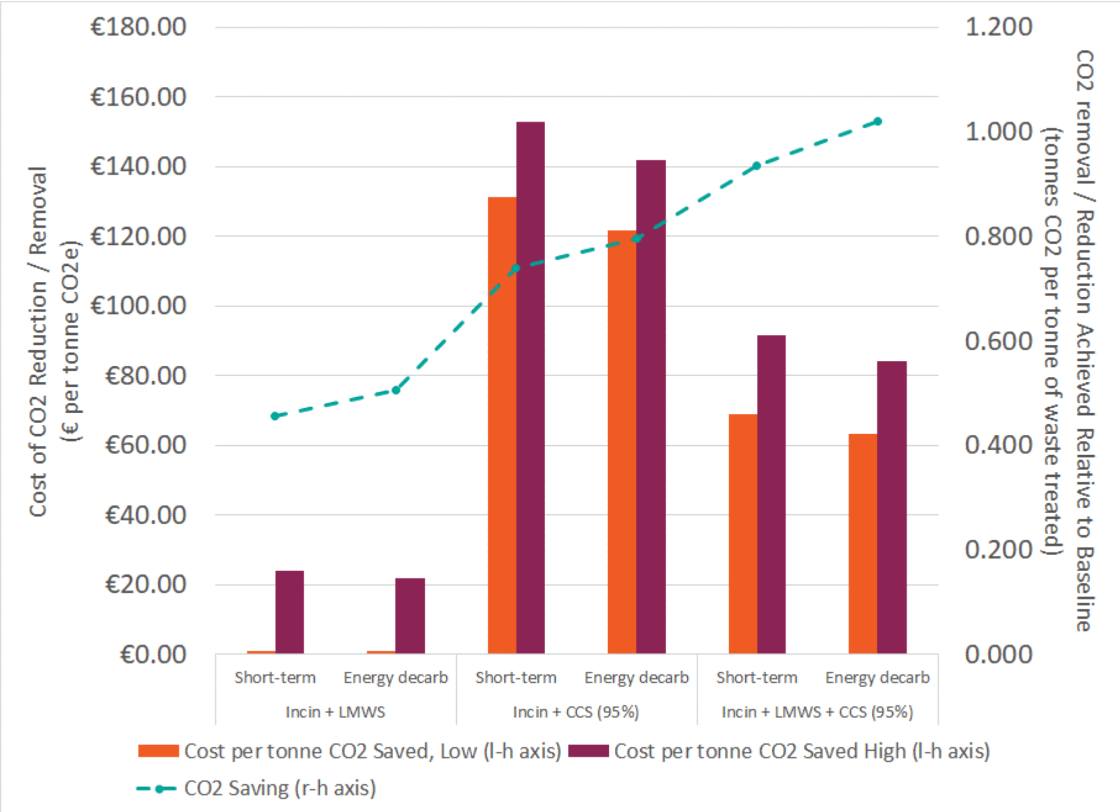
These technologies offer different levels of GHG reduction when compared to the baseline of LMW incineration directly. The LMWS process modelled here extracts materials (215kg per tonne of waste input), with the remaining residual waste incinerated. Less energy is exported than in the baseline situation, but that reflects a reduced amount of waste with a reduced carbon content and a lower calorific value. The remaining carbon in the residual waste is released as CO_2, with a reduced fossil component compared to the baseline situation. In the CCS case, reduction depends on capture rates of CO_2. Energy used in the CCS process is assumed to be derived from the incinerator itself (in line with our literature review), resulting in less energy being exported. In both the LMWS and CCS cases, transitioning to a completely decarbonised power sector results in a reduction of CO_2 emissions compared to the baseline. This is because the lower energy output from the incinerator becomes less relevant in the assessment.

Figure E - 1: Level of CO_2 Reduction Achieved Using Different Technologies (tonnes CO_2 per tonne of LMW Handled), Incinerator Generating Electricity Only (relative to baseline of incinerating all leftover mixed waste (LMW))



The two technologies have very different costs. We have assumed a 10% weighted average cost of capital. The LMWS net costs are more likely to fluctuate depending on the material revenues, while CCS costs may vary based on the energy price used. We have, however, used a central value from previous work for LMWS and assumed some variability for CCS costs. When we pull both costs and CO_2 reduction / removal together, the situation is as shown in Figure E - 2.

Figure E - 2: System Cost of GHG Reduction (€ per tonne CO_2 reduction achieved), Electricity Only Incinerator, 200kt Capacity



Although less CO_2 is abated, Incin + LMWS nevertheless proves superior on affordability. Costs are €1 – €24 per tonne CO_2 reduced in the current case, falling to €1 - €22 per tonne CO_2 reduced as energy is decarbonised. At the lower end, the costs are close to zero. This is dependent on revenues from material sales being as assumed in the central case. In earlier work, we flexed these values by +/- €9 per tonne of waste treated.

Using only CCS (Incin + CCS) reduces CO_2 at a higher rate, but it is relatively expensive at €132 – €153 per tonne CO_2 initially, dropping to €122-€143 per tonne CO_2 as energy is decarbonised. This cost is higher than recent EU allowance under the ETS which mostly range between €80-€90 per tonne CO_2 over the last 2 years, and only briefly exceeded €100.

The Incin + LMWS+CCS system achieves the highest level of CO_2 reduction of any of the scenarios, but more affordable per tonne of CO_2 reduced compared to the Incin + CCS system (being between 52%-60% of the equivalent costs). Costs are €69 – €92 per tonne CO_2 in the current case, falling to €63-€84 per tonne CO_2 as energy is decarbonised. Indeed, the costs per tonne of CO_2 reduced by the LMWS + CCS system are at levels at or below prices at which EU allowances have recently been trading. It should be noted that even if revenues from the sale of materials from the LMWS process were valued at zero, the costs would still be somewhat below those where CCS is deployed alone.

Key observations

The suggestion from the above is that:

- Incin + LMWS offers a potentially quick way to make a significant reduction / removal of greenhouse gases from incineration and at low cost;
- Higher levels of reduction / removal are achieved by Incin + CCS, but the costs are much higher (they will vary significantly, not least with the weighted average cost of capital used to purchase capture equipment, but also with local conditions); and
- The lower cost of CO_2 reduction from LMWS helps partially mitigate the much higher costs of CCS. Combining the two technologies (Incin + LMWS + CCS) offers a way to achieve the highest levels of removal / reduction at a lower *average* cost per unit of CO_2 reduction than where CCS is deployed alone (even though the marginal costs of CO_2 reduction from CCS remain high). Importantly, application of CCS would be compatible with LMWS, and complements its effect.

LMWS can be implemented in places where it might be difficult to apply CCS (it can, within reason, be separated spatially from the incineration facility). It can also be implementable relatively swiftly and with lower capital requirement.

This suggests a sequential logic, in which LMWS is applied as widely and as early as possible (subject to relevance of the waste streams) with CCS being deployed in its wake at facilities deemed most likely to be needed in future. The future of incineration facilities may indeed be shaped by which factors are likely to make CCS deployment more favourable, though equally, it should be considered that the case for deploying CCS may be greater at co-incineration facilities (such as cement kilns), which have purposes beyond treating waste, and for which CCS may be a necessary component of a broader decarbonisation pathway.

An important point is that the deployment of LMWS is likely to be a 'lower regret' solution with much reduced potential for lock-in. The fact that it seems eminently *compatible with* CCS suggests, as per our previous paper, a need for a rational scaling-back of incineration capacity in those Member States with too much capacity in place.[2] LMWS can also help support in the phasing down of capacity.

In subsequent work, we plan to explore these issues in further detail.

[2] Equanimator (2023) Enough is Enough: The Case for a Moratorium on Incineration, Report for Zero Waste Europe, September 2023.

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