A TECHNO-ECONOMIC ASSESSMENT OF CO_2 CAPTURE FROM INCINERATION FLUE GASES REUTILISING MUNICIPAL SOLID WASTE INCINERATION ASHES

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Abstract

Incineration ash, a by-product of municipal solid waste (MSW) incineration, is a heterogenous mix of minerals, metals, and glasses that is typically landfilled. In this study, the economic feasibility of retrofitting a calcium looping plant utilising incineration ash-derived sorbents to capture CO_2 from the tail-end of an MSW incineration waste-to-energy (WtE) plant was evaluated through a techno-economic assessment (TEA). A sensitivity analysis was also conducted to highlight key factors that can improve the economic viability of the retrofitted CaL system. Lastly, solid heat integration concepts using suspension preheaters for heat exchange were evaluated for their net impacts to the energy efficiency and economics of the WtE-CaL system.

Keywords

Techno-economic analysis, Post-combustion CO2 capture, Negative emissions, MSWI ash reutilisation, Calcium looping

Introduction

Waste-to-Energy (WtE) through municipal solid waste (MSW) incineration is a key waste management strategy to reduce the mass and volume of landfilled wastes, especially for land-constrained areas such as urban centres. However, this process releases large amounts of CO_2 into the atmosphere and the ash that remains after burning is often sent to the landfill after some metal recovery. After bulk metal recovery, the remaining ash contains a mix of minerals, glasses, and unrecovered metals with particle size dependent physicochemical properties that can potentially be exploited through different reutilisation strategies (Loginova *et al.*, 2019).

In this study, the finer fraction (150 – 315 μm) of incineration bottom ash (IBA), which contains a significant fraction of CaO and $CaCO_3$, is used to derive sorbents for the calcium looping (CaL) process. Thereafter, a techno-economic assessment was performed to evaluate the feasibility of retrofitting a CaL plant using ash-derived sorbents to capture CO_2 from a $200MW_{th}$ WtE plant.

Methods

To enumerate the size and economics of such a system, the performance of the ash-derived sorbent throughout long series of carbonation-calcination cycles was first estimated

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by performing a 100-cycle fluidised bed CaL experiment and fitting the cyclic capture capacity data obtained to an existing mathematical model for CaL sorbent deactivation. The results were then used to build a detailed process model of the CaL plant in Aspen Plus® using 4 different supplementary fuels in the calciner, namely, biomass charcoal (BC), solid recovered fuel (SRF), coal, and natural gas (NG).

The economic analysis was performed using the bottom-up approach where individual cost components were estimated using Aspen Process Economics Analyzer and reference cost scaling equations. Key performance indices (KPI) used to evaluate CO_2 capture technologies such as the levelised cost of electricity (LCOE), levelised cost of carbon abatement (LCCA), and specific primary energy consumption per carbon avoided (SPECCA) were presented as the main results of this study. A sensitivity analysis through ±20% variations in 14 process and economic parameters was also performed to determine the key areas for further optimisation. Finally, solid heat integration (SHI) concepts utilising suspension preheaters, which are commonly used in cement plants, are explored. Crucially, the viability of the heat integration schemes was evaluated by calculating the impacts of the modifications to both the energy efficiency and economic performance of the WtE-CaL system.

Results

While the CaL process incurs high capital costs, the sale of additional electricity generated from the heat recovery steam cycle partially mitigates the costs of implementation. Moreover, capturing biogenic CO_2 from WtE plants provides an opportunity for net negative emissions. The resulting LCCA ranges from 89 (SRF) to 184 (coal) USD /t_{CO2}, which is competitive with other bioenergy with CO_2 capture and storage (BECCS) technologies (Fajardy *et al.*, 2021). The biogenic fuels also result in lower SPECCA of 4.5 (BC) and 7.6 (SRF) MJ_{th} /$t_{CO2,}$ which are comparable to values from other post combustion CCS technologies e.g. monoethanolamine scrubbing and other studies of CaL systems, ranging from 3.1 to 7.4 MJ_{th} /kg_{CO2} (Bonalumi *et al.,* 2014; Voldsund *et al.*, 2019). The levelised costs and SPECCA for each fuel type are illustrated in Figure 1.

The sensitivity analysis reveals that further improvements to the KPIs can best be achieved through reducing the energy penalties of processes such as the O_2 production and CO_2 conditioning. Regulatory intervention through favourable carbon pricing and waste management policies are also key factors that could improve the economic feasibility of the system.

The SHI configurations are also shown to effectively reduce fuel and O_2 requirements by up to 22%, thereby lowering annualised costs by up to 11.5%. The KPIs obtained from the SHI study suggest that while the multi-staged suspension preheaters result in even lower fuel and O_2 requirements compared to their single-staged counterparts, the diminished improvements may not justify the increased costs.

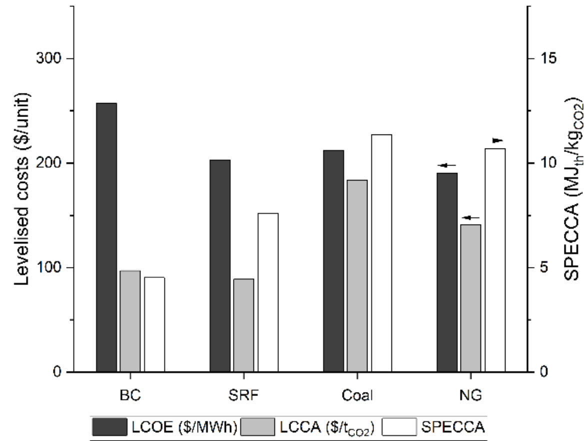

Figure 1. Levelised costs and SPECCA values for the WtE-CaL system using different fuels

Conclusion

This study demonstrates that CO_2 capture from WtE plants with CaL using ash-derived sorbents could be a cost-effective way of reutilizing incineration ash while achieving net negative emissions and accelerating the global decarbonization effort. Key factors that can further improve the feasibility of implementation include the optimization of CO_2 processing and O_2 production, higher carbon pricing, and the potential further valorization of sorbent purged form the WtE-CaL system.

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