# A Comparison between Energy Recovery Systems for Municipal Solid Waste concerning with Energy Balance and Life Cycle $CO_2$ Emission

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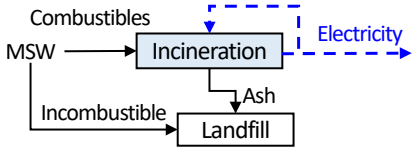
## INTRODUCTION

To reduce the problems caused by disposal of organic waste in landfill, mechanical-biological treatment (MBT) system that consists of mechanical sorting and biological process, have been employed as one of the methods for mixed municipal solid waste (MSW) management. In MBT system, not only organic stabilization but also energy recovery is possible in the form of either biogas or solid recovered fuel (SRF) (Velis, Longhurst et al., 2009). The present study compared the energy efficiency and life cycle $CO_2$ emission from two types of MBT and other energy recovery systems. To apply a real situation, Asahikawa city data was utilized. The parameters for operation and utility consumption were referred from the literature or measured data of waste samples collected from operating facility (Asahikawa city, 2018; Ham, 2020). Sensitivity analysis for critical parameters in each system was carried out, and possible improvement in energy recovery was estimated by postulating the ideal condition in each system.

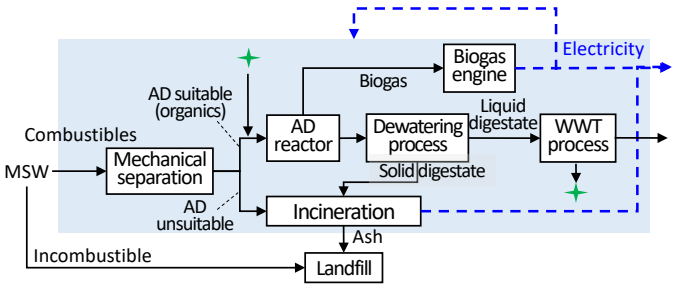
## COMPARED SYSTEMS

Four systems for energy recovery from MSW were compared as to energy balance and $CO_2$ emission (Fig. 1). Two of these were a type of MBT system, which were a combined MBT of anaerobic digestion (AD) and incineration, and bio-drying MBT. The other two systems were incineration with high rate power generation and refuse derived fuel (RDF) production system. Energy was recovered as a form of electricity in all systems.

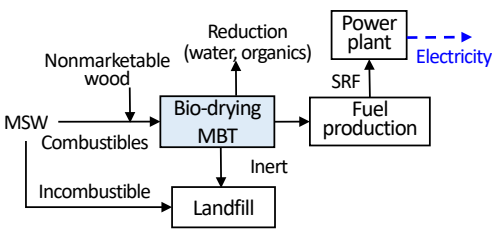
(a) S1: Incineration with energy recovery




(b) S2: Combined system (AD + incineration)




(c) S3: Bio-drying MBT system




(d) S4: RDF production system

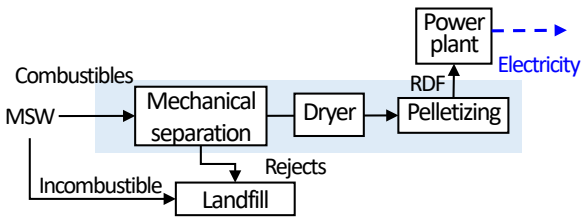



**Figure 1 Process and material flow of the four systems (shaded: boundary of utility consumption)**

## RESULTS AND DISCUSSION

### Energy balance and life cycle $CO_2$ emission

S2 recovered the more energy than S1 due to the additional energy recovery from the biogas engine with high power generation efficiency (Fig. 2). However, high electricity consumption in S2 reduced the net recovery. In S3, organic degradation resulted decrease in total energy content of the fuel materials, but high-power generation efficiency of the power plant produces more electricity than S1 and S2, and low electricity and fuel consumption, consequently resulted in the higher net recovery. S4 recovered the highest energy due to low moisture content of the fuel material. However, considerable fuel consumption for thermal drying led to low net efficiency. The $CO_2$ emission follows the similar trend to energy balance that indicates electricity and fuel consumption are the major sources of emission. Overall, S3 showed the highest energy efficiency and the lowest $CO_2$ emission.

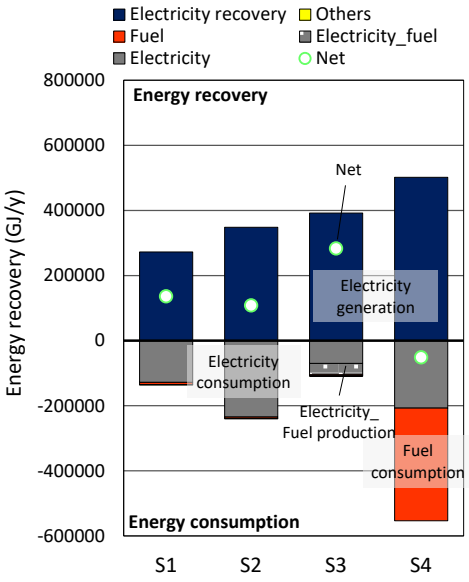



**Figure 2 Energy balance and net energy recovery**

### Sensitivity analysis and energy efficiency under ideal conditions

Sensitivity analysis was carried out with a fixed sensitivity of ± 20%, and possible maximum (Max.) and minimum (Min.) values to reflect a reality. The power generation efficiency of the entire system, the fuel consumption of S4, and the recovery rate of S3 were highly sensitive. On the other hand, in the possible situation presented by Max. and Min. values, the AD performance in S2 and the electricity consumption of all systems (except for S3) showed high variation. By improving these parameters can be the most effective solution for high energy performance. Under the ideal conditions of parameters, the energy efficiency in the combined system was increased to be compatible with the bio-drying MBT.

## CONCLUSION

Bio-drying MBT can be a viable option for MSW treatment with high energy recovery compared to other energy recovery option. The combined system, another type of MBT, showed low energy efficiency due to high electricity consumption, but the efficiency can be increased to be compatible with the bio-drying MBT with the improvement of AD performance and power generation efficiency.

## REFERENCES

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