

## New Ways of Looking at Energy from Municipal Solid Waste

With an ever growing population and consumerism at its highest, the amount of waste that is generated has become a serious problem. As resources are being depleted and landfills are reaching capacity, getting the most out of municipal solid waste (MSW) has become increasingly important.

In the past, we've relied on incinerators to both reduce the burden on landfills while also recovering some of the energy embodied in our waste. Incinerators have done society a great service, but their ability to recover energy is limited, they produce toxic gasses and they emit large amounts of greenhouse gasses (GHGs). Pollution control is very expensive and the revenue from electricity production is low, so incinerators often rely on additional funding (tipping fees) to survive.

Since the 1920s, when incineration began being a common waste disposal method, there have been many technological advancements. Various companies are now developing waste disposal solutions designed to get the most out of MSW, while also having the smallest environmental footprint. Some of these include gasification, pyrolysis and anaerobic digestion (AD). Each technology brings something new to the table and it can be difficult to decide which one to implement.

On one hand, gasification can transform waste into syngas (mainly CO, CO<sub>2</sub>, H<sub>2</sub>, H<sub>2</sub>O and CH<sub>4</sub>) which can be refined and transformed into new products, or simply used to generate electricity. Although the waste needs to be sorted to a higher degree when compared to incineration, it is still able to divert a large fraction of MSW away from landfill.

Pyrolysis, unlike gasification, is best suited for treating the plastic fraction of MSW, producing hydrocarbon fuels that displace those obtained from crude oil refineries. Although plastics are only a small fraction of MSW, pyrolysis can get more out of plastics than if they were gasified or incinerated. This is because pyrolysis limits the breaking down of the plastics and obtains valuable fuels. By limiting the degradation of the plastics, less energy input is needed for processing and the products contain more energy. This is especially true when using newer continuous pyrolysis technologies.

Complementary to pyrolysis is AD. This process treats only the organic fraction of uMSW and produces biogas (mainly methane and CO<sub>2</sub>) which can be upgraded and sold as renewable natural gas or used to generate electricity. It is also worth noting that AD also produces a biproduct call digestate that, if properly treated, can be used as fertilizer.

Lastly, it is not only waste-to-energy systems that have seen great advancements over the last few decades. New and improved, cost-effective sorting equipment have made their way onto the market. Sorting systems are now capable of separating the various fractions of MSW (such as organics, plastics, metals, glass, rocks, etc.) at a much lower cost than traditional sorting means. Although the materials obtained from sorting are dirty and the level of separation is limited (for

example: plastics are not sorted by resin type, making them unsuitable for recycling without further processing), these new systems can be used to bridge the gap between pyrolysis and AD, providing a suitable feedstock for both operations and diverting a large fraction of MSW away from landfill.

To give a bit of perspective, consider the following example:

A modern urban city has a population of 500,000 and produces 360,000 tons of MSW per year. Although MSW composition is highly variable, for the sake of this example it, it is approximated based on Metro Vancouver's study titled *2016 Waste Composition Monitoring Program* which provides the following data:

| <b>Component</b>                   | <b>Composition</b> |
|------------------------------------|--------------------|
| Compostable Organics               | 27%                |
| Plastic                            | 19%                |
| Paper                              | 19%                |
| Non-Compostable Organics           | 11%                |
| Building Material                  | 9%                 |
| Household Hygiene                  | 6%                 |
| Metals                             | 3%                 |
| Glass                              | 3%                 |
| Electronic Waste                   | 2%                 |
| Household Hazardous                | 1%                 |
| Fines                              | 1%                 |
| Compostable Products and Packaging | <1%                |
| Bulky Objects                      | <1%                |

For this example, it will also be important to characterise the composition of the plastic fraction of the MSW. Therefore, it will be assumed that this plastic waste has a composition similar to the described in the article titled *Municipal Plastic Waste Composition Study at Transfer Station of Bangkok and Possibility of its Energy Recovery* by Areeprasert et al., as shown below:

| <b>Component</b> | <b>Composition</b> |
|------------------|--------------------|
| HDPE             | 57.4%              |
| LDPE             | 17.4%              |
| PP               | 7.3%               |
| PET              | 5.9%               |
| PVC              | 2.2%               |
| Other            | 5%                 |

To begin, if all of this waste is sent for incineration, it can be assumed that no sorting takes place and the entire 360,000 tons of garbage is incinerated to produced electricity. Since modern incinerators can yield about 550 kWh of electricity per ton of MSW, the net gain from incineration would be 198 GWh of electricity per year.

On the other hand, if the waste was sent to a waste gasification plant, it can be assumed that metals, glass, building waste and electronic waste would be sorted out from the rest, leaving about 298,800 tons of waste to be treated. Since the more advanced gasification technologies can recuperate up to a maximum about 1000 kWh of electricity per ton of MSW, it is assumed that this plant can produce a total of 298.8 GWh of electricity per year.

The last scenario is the case in which newer sorting technologies are combined with pyrolysis and AD. It can be assumed that the organics and paper are recovered and treated through AD, while the plastics are sorted from the rest and sent to a pyrolysis plant.

With regard to pyrolysis, it can be assumed that 80% of the 68,400 tons of plastic waste consists of mainly HDPE, LDPE and PP, providing a feedstock of 54,720 tons. The heavier plastic types (such as PVC and PET) can be removed by density and sold separately. By pyrolyzing the 80%, we obtain 42.85 million liters of ultra-low sulfur diesel containing 420.9 GWh of energy. The side products are in the form of coke, naphtha, gas and heavy oil, which could provide 51.3 GWh of electricity.

For AD, the total amount of feedstock would be about 57% of the MSW, which is 205,200 tons or organic matter. Assuming a production of 200 kWh of electricity per ton of organic material, this process would generate 41 GWh of electricity per year. The process would also yield about 185 thousand liters of digestate which could be used as a fertilizer once properly treated.

In summary, the energetic and resource recovery for each case of the example is estimated as:

| <b>Process</b> | <b>Electricity<br/>(GWh)</b> | <b>Fuel<br/>(GWh)</b> | <b>Digestate<br/>(liters)</b> |
|----------------|------------------------------|-----------------------|-------------------------------|
| Incineration   | 198.0                        | -                     | -                             |
| Gasification   | 298.8                        | -                     | -                             |
| Pyrolysis + AD | 92.3                         | 420.9                 | 185,000                       |

From this example, it is clear that the greatest yields and profits come from a combination of pyrolysis and AD. Not only does it obtain valuable fuels and fertilizer, but the total energy obtained is about 170% of the amount obtained from gasification and about 260% of the amount obtained from incineration.

Given that new technologies make it possible to sort the various components of MSW at a reasonable cost, waste management systems should consider treating each component separately. Not only does this ensure that each waste component is treated optimally, but it encourages the implementation multiple small-scale operations which greatly reduce transport costs and GHG emissions.