Carbon Footprint of Plastic and Sludge Waste Streams in Singapore

Xin He[1], Dingding Yao[1], and Chi-Hwa Wang[2*]

1 NUS Environmental Research Institute, National University of Singapore,

1 Create Way, Create Tower #15-02, Singapore 138602

2 Department of Chemical and Biomolecular Engineering, National University of Singapore, 4 Engineering Drive 4, Singapore 117585

Keywords: plastic waste, sludge, waste streams.

Presenting author email: chewch@nus.edu.sg

1.33 tonnes of solid waste per capita was generated in 2018 in Singapore, which was about 9,000 tonnes less than in 2017. However, quantity of waste recycling was also decreased by 9,000 tonnes (lowering to 0.80 tonnes per capita). This led to an overall decrease in recycling percentage from 61 % to 60 % in 2018.

In this study, we proposed to convert plastic waste into oil products using two approaches: gasification (with syngas synthesis) and pyrolysis (also known as thermal depolymerization). The gasification approach typically involves converting plastic into syngas (CO, CO_2, H_2O and H_2) under high temperature (900 – 1,100°C), and the syngas is further catalytically synthesized into oil products. The cleanliness of the syngas produced is a major concern for downstream synthesis process. Although this problem has been overcome in coal gasification, it's still relatively unproven for less consistent feedstocks, such as plastic waste and general municipal solid waste. The pyrolysis approach involves a lower temperature (typically 400 – 600°C) in which long polymer chains are broken shorter hydrocarbon similar to products from oil refinery. In this study, the pyrolysis approach is preferred for plastic waste management due to its lower energy intensity and higher overall yield of oil products.

Different market options for those oil products derived from plastic waste were considered. The first option is to introduce the oil products as feedstock of oil refinery plants. However, due to the fact that these refineries are optimized for crude oil feedstock, a change in composition of the feedstock or contaminants in the feedstock may upset the refinery product quality and plant operations. The second option is to use the oil products as blendstocks, the usage of which depends on their physical properties and compositions. Blendstocks are the unfinished oils that are blended for the final refined products (such as diesel or gasoline) and the derived oil products can be employed as third-party blender products for diesel refinery. The third option, which is considered as the major end market option in this study, is to introduce the derived oil products as fuels for transportation and heating.

The GHG emission reducing potential of recycling of plastic waste was calculated using life cycle assessment.

Currently, the electricity energy recovered from sludge digestion can only account for about 30-50 % of the electricity consumed in Water Reclamation Plant, mainly due to the low methane production yield of sludge digestion. Co-digestion of sewage sludge and other high organic waste has been investigated to enhance the methane production but reduce the solid residue volume. In this study, the sewage sludge is proposed to be anaerobically co-digested with food waste in an integrated waste management facility.

The GHG emission reduction potentials of energy recovery and waste-recycling strategies for the three major waste streams discussed (with by-products used to replace industrial products) are quantified. Full implementation of the proposed waste strategies is likely to yield the new overall recycling percentage of 83%, which is about 20% more than the existing recycling percentage. This will also be 10% more than what Singapore has pledged for 2030. For high-density but small low-lying cities, such energy recovery strategies are also very useful in saving space set aside for landfills. In Singapore's case, the Pulau Semakau Landfill is expected to be full in the next 15 years (by 2035).

Calculations showed that by diverting plastic waste away from incineration, the reduction in GHG emission amounts to 1.27 tonne per tonne of plastic waste; this represents a 63% reduction. The reduction is achieved by utilizing the light hydrocarbon gas for heat recovery and replacing fuel oil in the market. As a result, the BAU system emits a net total of 1,785.8 kg of GHGs whereas the proposed system emits only 698 kg per tonne of plastic waste recycled.