

# Carbon Footprint of Plastic and Sludge Waste Streams in Singapore



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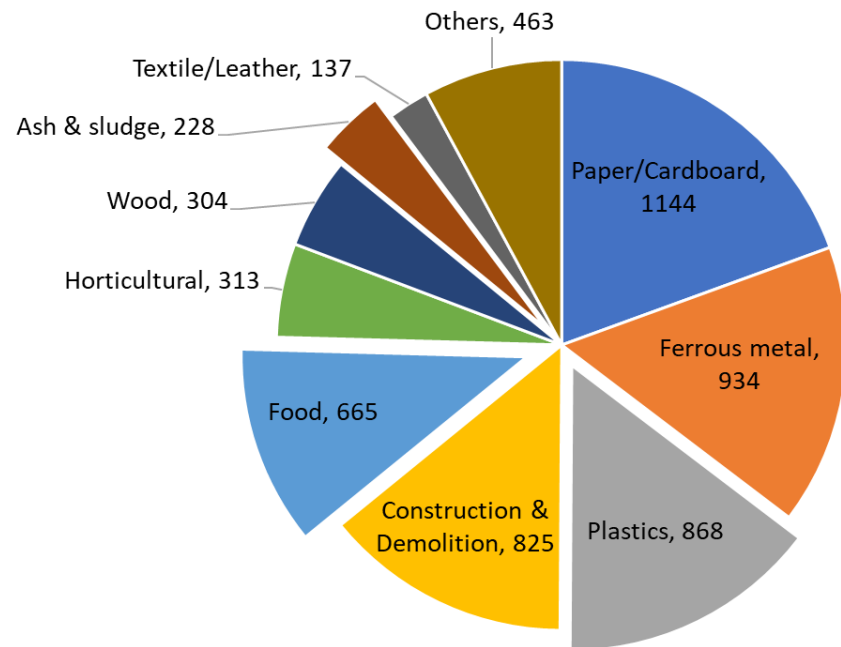
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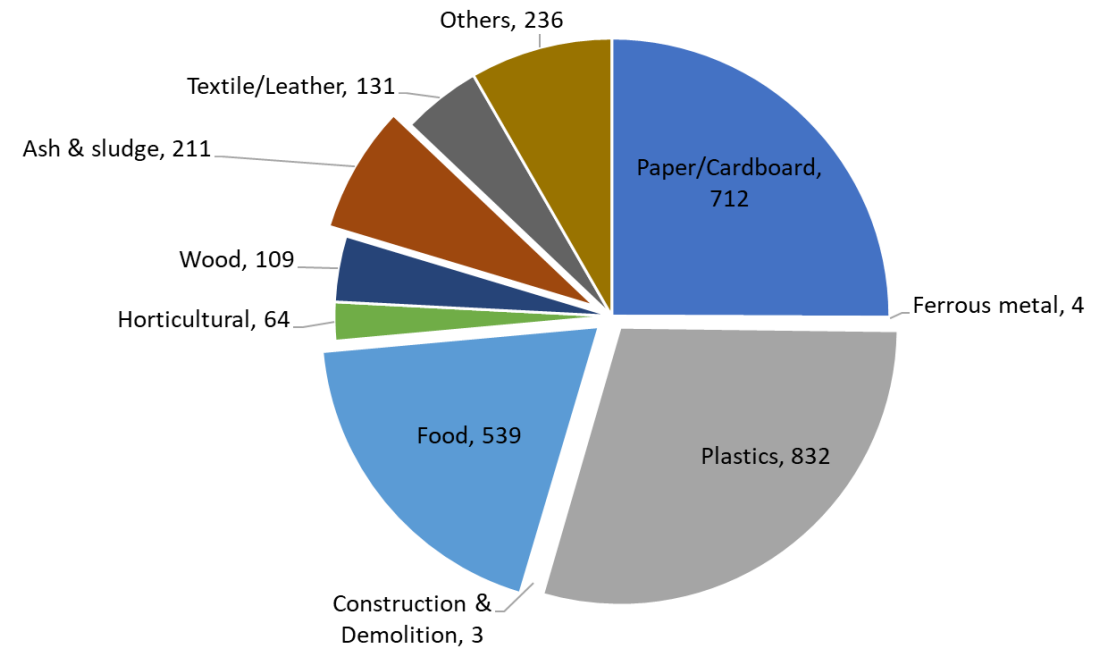
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# Introduction

- Rapid growths of urbanization and megacities challenge the urban waste management systems
- In Singapore, 5.88 million tonnes of waste were generated in 2020
  - The waste recycling rates of “Plastic” and “Ash & Sludge” are less than 10%



2020 waste generated in Singapore ['000 tonnes]



2020 waste disposed in Singapore ['000 tonnes]

# Carbon Footprint of Plastic Waste

- The COVID-19 pandemic has resulted in growing of plastic use due to the protective measures introduced to suppress the outbreak.
  - Personal protective equipment (PPE): mask, gloves, shield, fast test kit.



Aluminum strip: ~0.5 g aluminum  
Filter: ~2 g Polypropylene (PP)  
Mask: ~9 g PP  
Rubber strap: ~0.5 g rubber

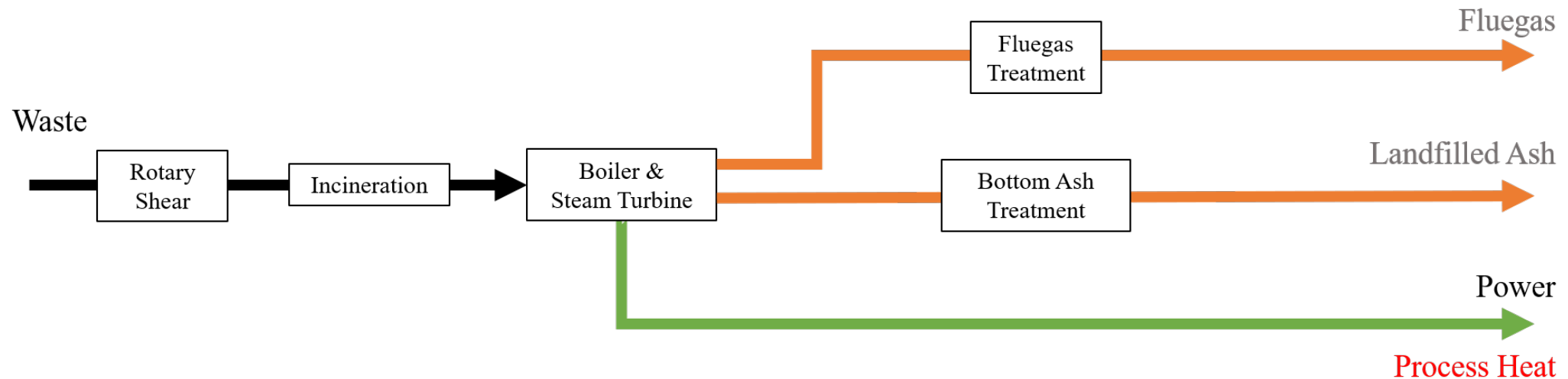


Mask layer: ~1.3 g PP and ~0.7 g cellulosic fabric  
Nose wire: ~0.2 g High Density Polyethylene (HDPE)  
Ear loops: ~0.4 g Polyetherimide

- Food delivery during lockdown or movement restriction.
- The environmental consequences overshadowed by urgent health issue should be analyzed.

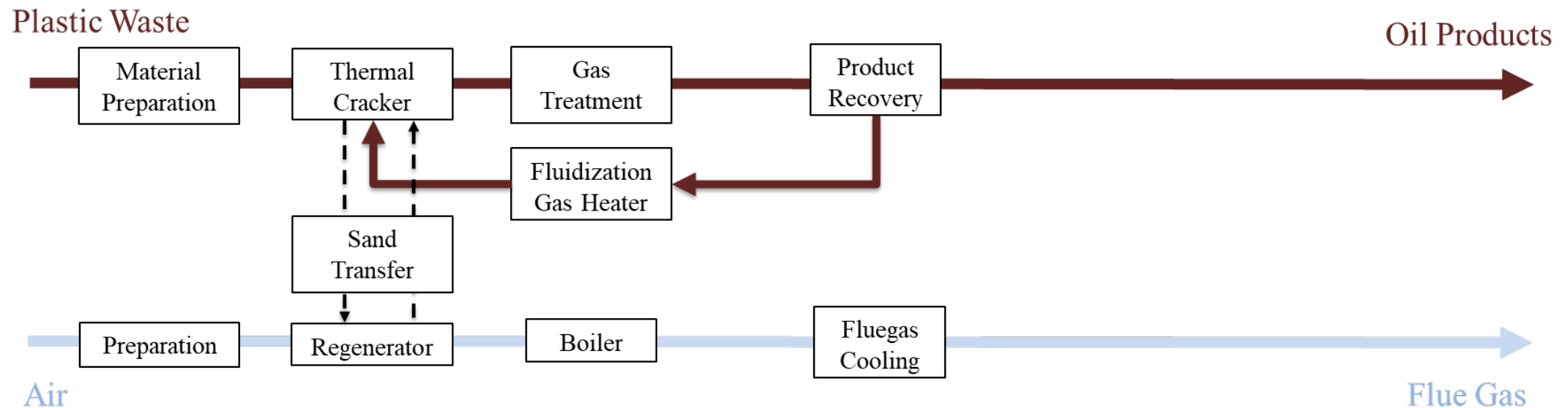
# Carbon Footprint of Plastic Waste

- Singapore general plastic waste consists of 40% polyethylene, 17% polyvinyl chloride, 12% polypropylene, 4% polystyrene, 4.8% polyethylene terephthalate and 22.2% other mixed compositions.
- In Singapore, the current plastic waste treatment is incineration, which is considered as the Business-as-usual (BAU) scenario.



# Carbon Footprint of Plastic Waste

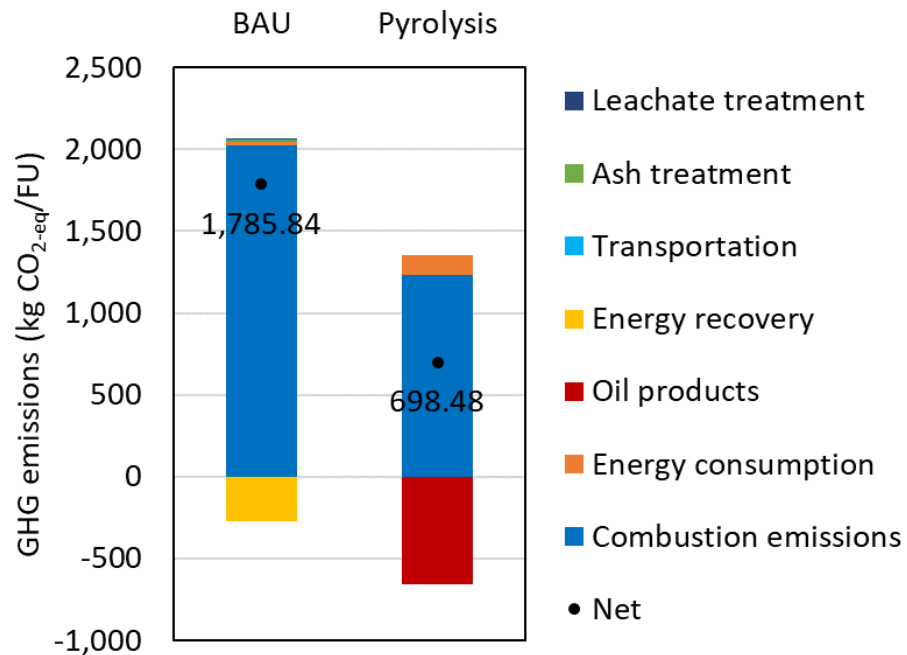
- In this study, the pyrolysis approach is preferred for plastic waste management due to its lower energy intensity and higher overall yield of oil products.



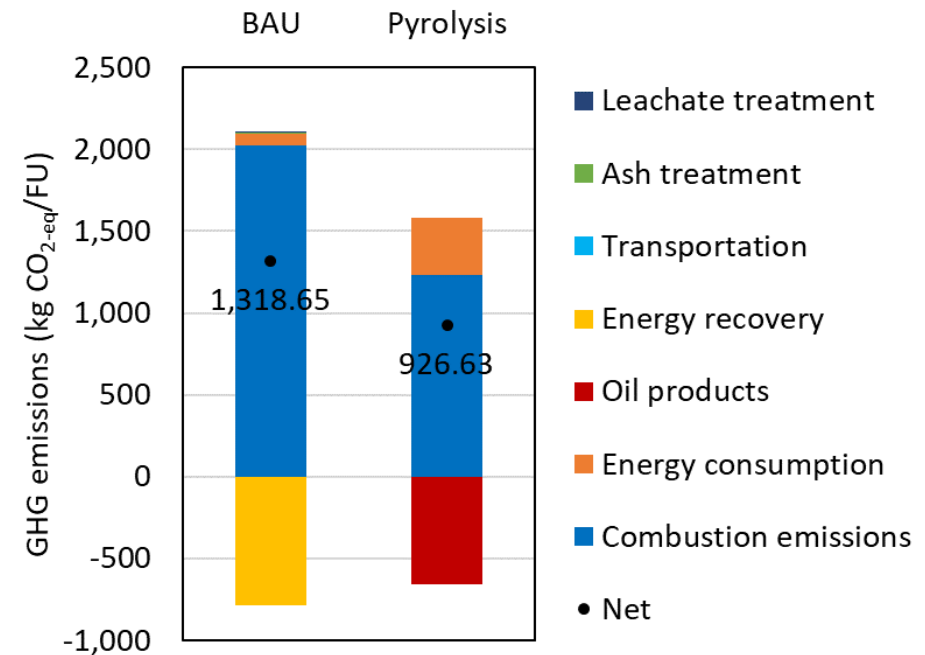
- Different market options for oil products derived from plastic waste:
  - Fuel oil substitute (in this study).
  - Potential feedstock of oil refinery plants: refinery wax, naphtha, or oil substitute.

# Carbon Footprint of Plastic Waste

- Life-cycle greenhouse gas (GHG) results based on different local electrical power
  - Functional Unit is 1 tonne of Singapore plastic waste.



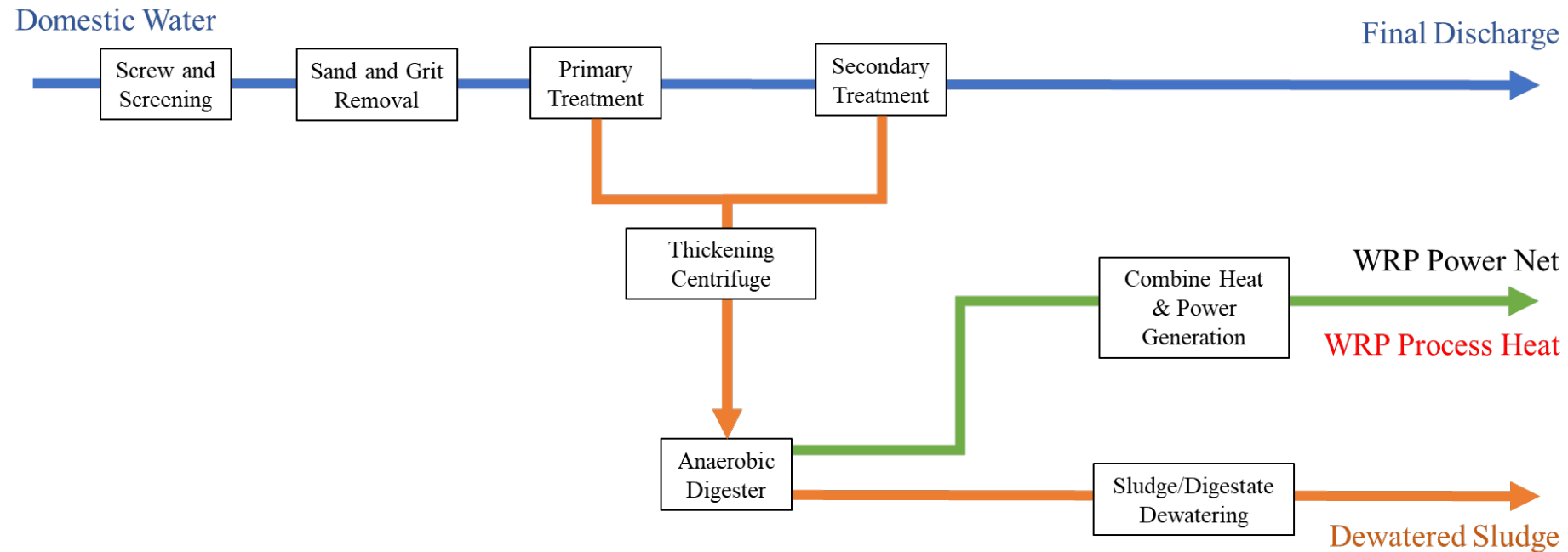
Singapore general electricity [0.419 CO<sub>2</sub><sub>eq</sub>/kWh]



Coal-fired electricity [1.211 CO<sub>2</sub><sub>eq</sub>/kWh]

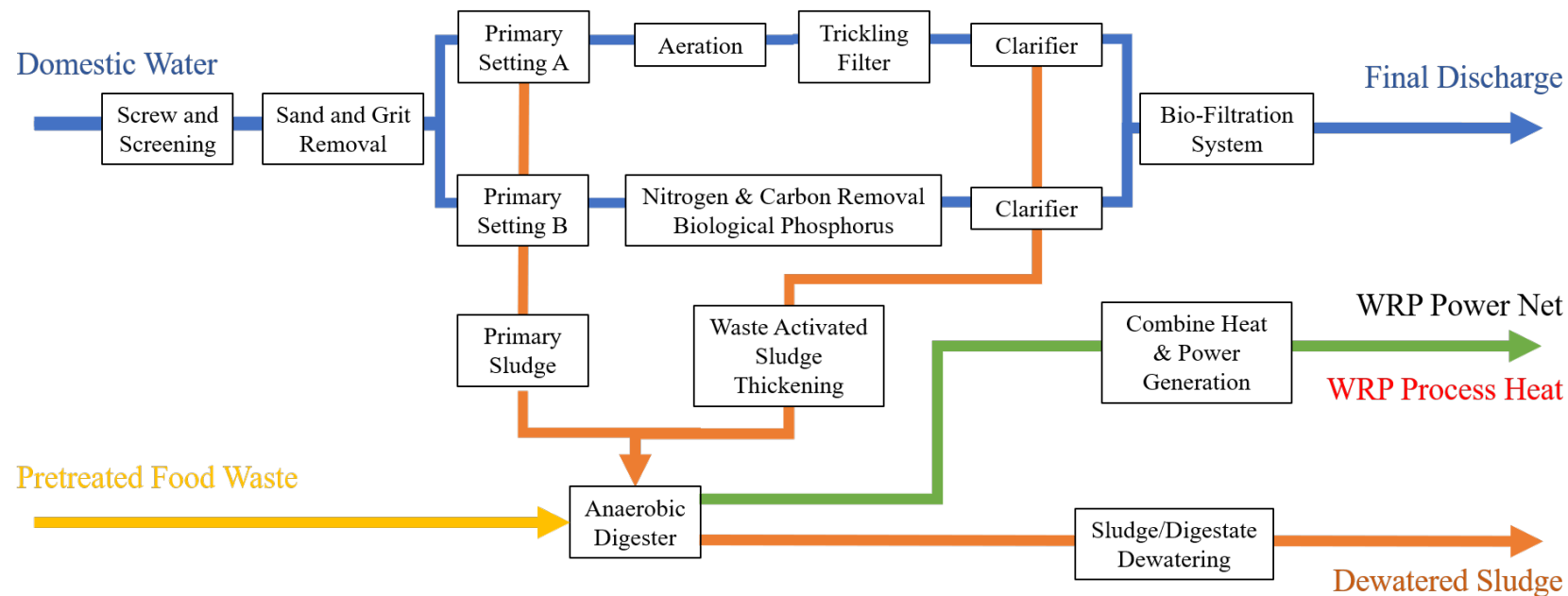
# Carbon Footprint of Sewage Sludge

- Sewage sludge is the solid waste generated in wastewater reclamation plant
  - Residue of anaerobic digestion (AD) unit.
- In Singapore, the current sewage sludge treatment is incineration.



# Carbon Footprint of Sewage Sludge

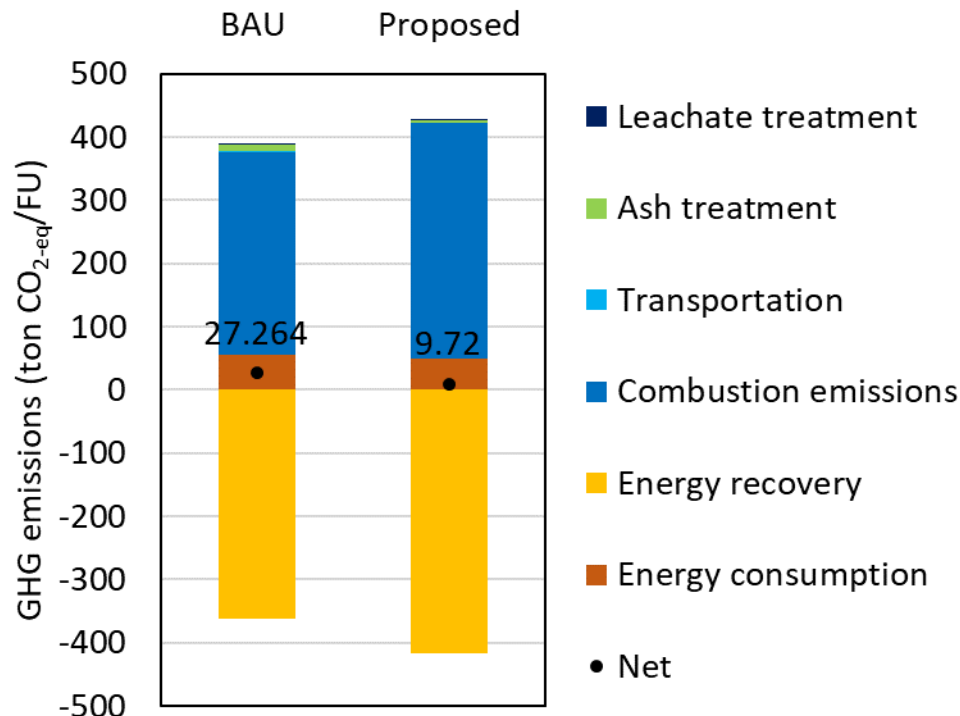
- In this study, the anaerobic co-digestion of sewage sludge and food waste is proposed
  - The Singapore sewage sludge consists of 8.2% moisture, 50.8% volatile, 15.2% fixed carbon, and 25.8% ash.
  - The Singapore food waste consists of 84 % organic fraction and 16 % impurities.



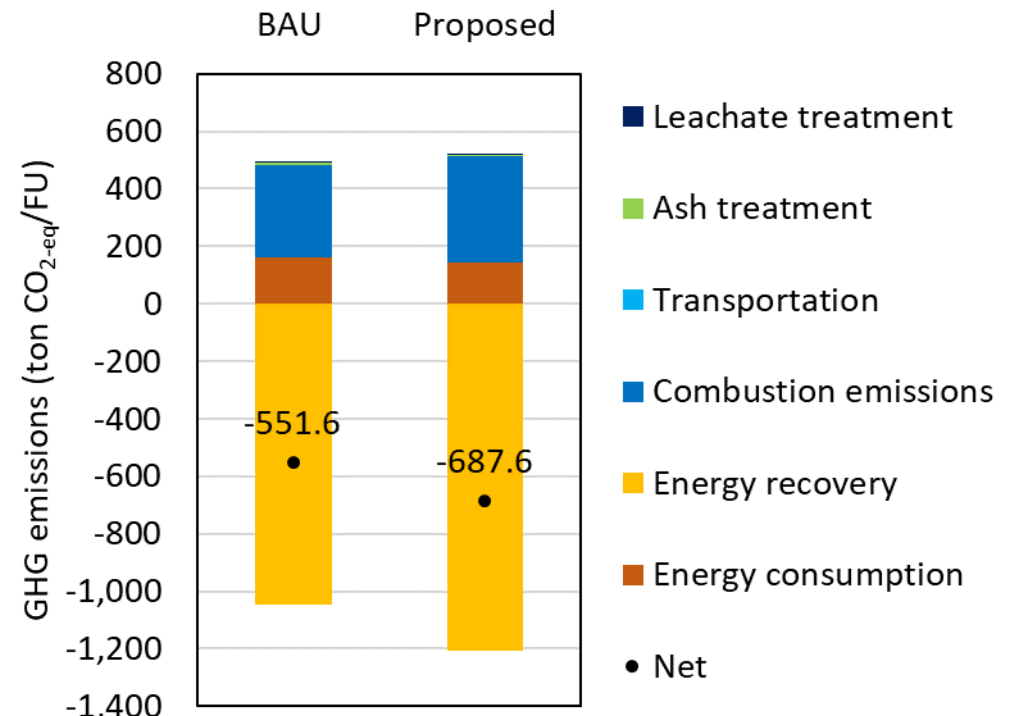


# Carbon Footprint of Sewage Sludge

- Life-cycle greenhouse gas (GHG) results based on different local electrical power.
  - Functional Unit is 1 tonne domestic sewage sludge and 1 tonne Singapore food waste.



Singapore general electricity [0.419 CO<sub>2</sub>eq/kWh]



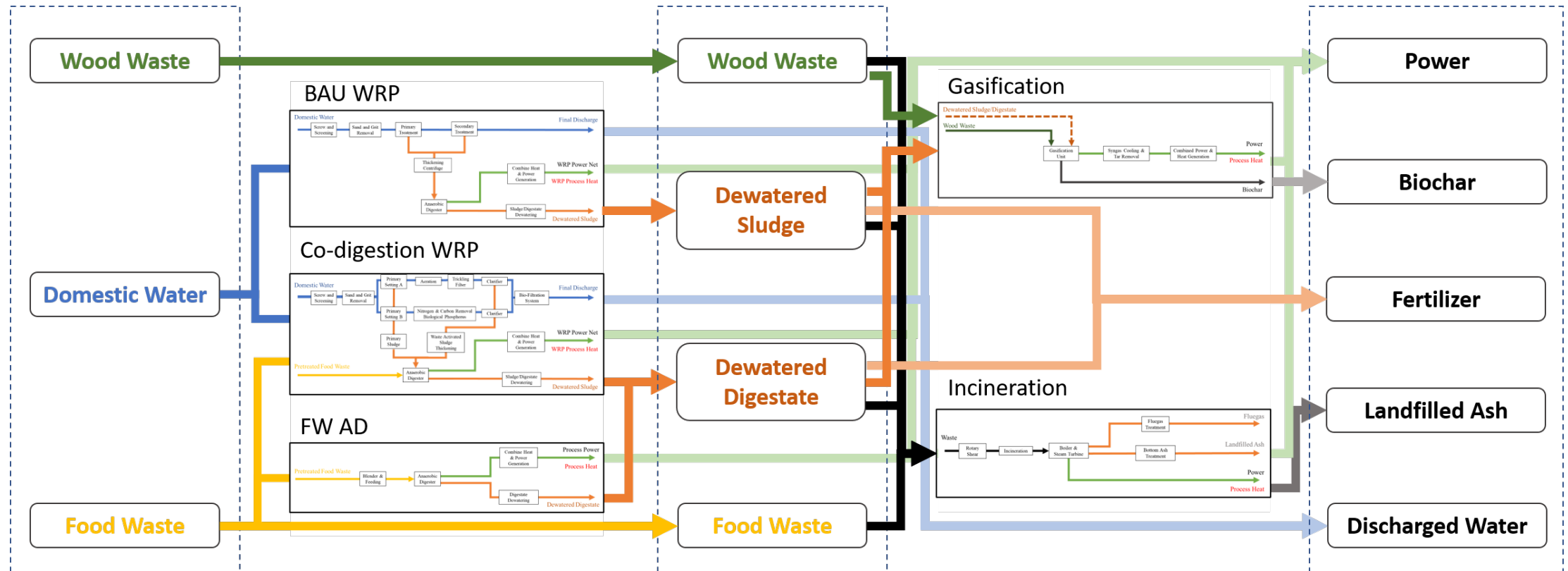
Coal-fired electricity [1.211 CO<sub>2</sub>eq/kWh]

# Conclusions

- By diverting the plastic waste away from incineration, a reduction of 61% in GHG emission amount can be reached.
- The sewage sludge diverted from incineration is proposed to be co-digested with food waste at a 1:1 ratio.
- A reduction of 59% in GHG emission amount can be reached based on Singapore general electricity.
- The GHG emission of annual Singapore plastic waste and sewage sludge can be reduced from 1.82 million tonnes CO<sub>2eq</sub> to 0.71 million tonnes CO<sub>2eq</sub>.

# Future Works

- Carbon footprints of all feasible waste management solutions in energy-water-food nexus.



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