Life Cycle Environmental Impact of PET Water Bottles

Introduction

Single-use plastic water bottles can provide convenience, but their use is a controversial topic due to their environmental concerns. In 2021, polyethylene terephthalate (PET) packaging accounted for 44.7% of single-serve beverage packaging in the US[i]. The following is a review of the environmental impacts throughout the life cycle of a standard 500 mL PET water bottle, primarily energy consumption and greenhouse gas (GHG) emissions.

Material Production

Fossil fuels, namely crude oil and natural gas are extracted and refined to produce ethylene glycol (EG) and purified terephthalic acid (TPA). EG and TPA are combined to form PET resin. The PET resin is then pelletized to form PET resin pellets to be used in bottle manufacturing.

Environmental impact estimates:

Energy consumption: 70 – 83 MJ/kg of PET resin[ii iii iv] ≈ 1.06 – 2.463 MJ/500mL bottle

GHG emissions: 2.19 – 2.733 kg CO_2-eq/kg of PET resin[ii iv] ≈ 0.0379 – 0.0625/500mL kg CO_2-eq bottle

Waste produced: 0.091 – 0.141 kg waste/kg of PET resin[ii iv] ≈ 0.0014 – 0.0042 kg waste/500mL bottle

Bottle Fabrication

The PET resin pellets are injection molded to form tubes. The tubes are then stretch blow molded to form single-use PET water bottles. 1 kg of PET resin can be used to produce 0.877 kg of finished 500 mL bottles[v] or 33.7 – 65.94 bottles, depending on the mass of the bottle (13.3 – 26 g)[v vi vii].

Environmental impact estimates:

Energy consumption: 8.388 – 20 MJ/kg of bottle[iii v viii] ≈ 0.1116 – 0.52 MJ/500mL bottle

GHG emissions: 0.034 – 0.046 kg CO_2-eq/ 500 mL bottle[v]

Bottling Operation

Water is typically treated and filtered through processes such as reverse osmosis, UV, and ozone treatment. The plastic water bottles are then filled with the treated water and packaged for distribution.

Environmental impact estimates:

Energy consumption: 1 x 10^{-4} – 0.1617 MJ to treat each L of water[iii vi]

0.003 – 0.006 MJ/500 mL PET bottle filled[iii vi]

GHG emissions: 0.01 kg CO_2-eq/L of water treated[vi]

2 x 10^{-4} kg CO_2-eq/ 500mL PET bottle filled[vi]

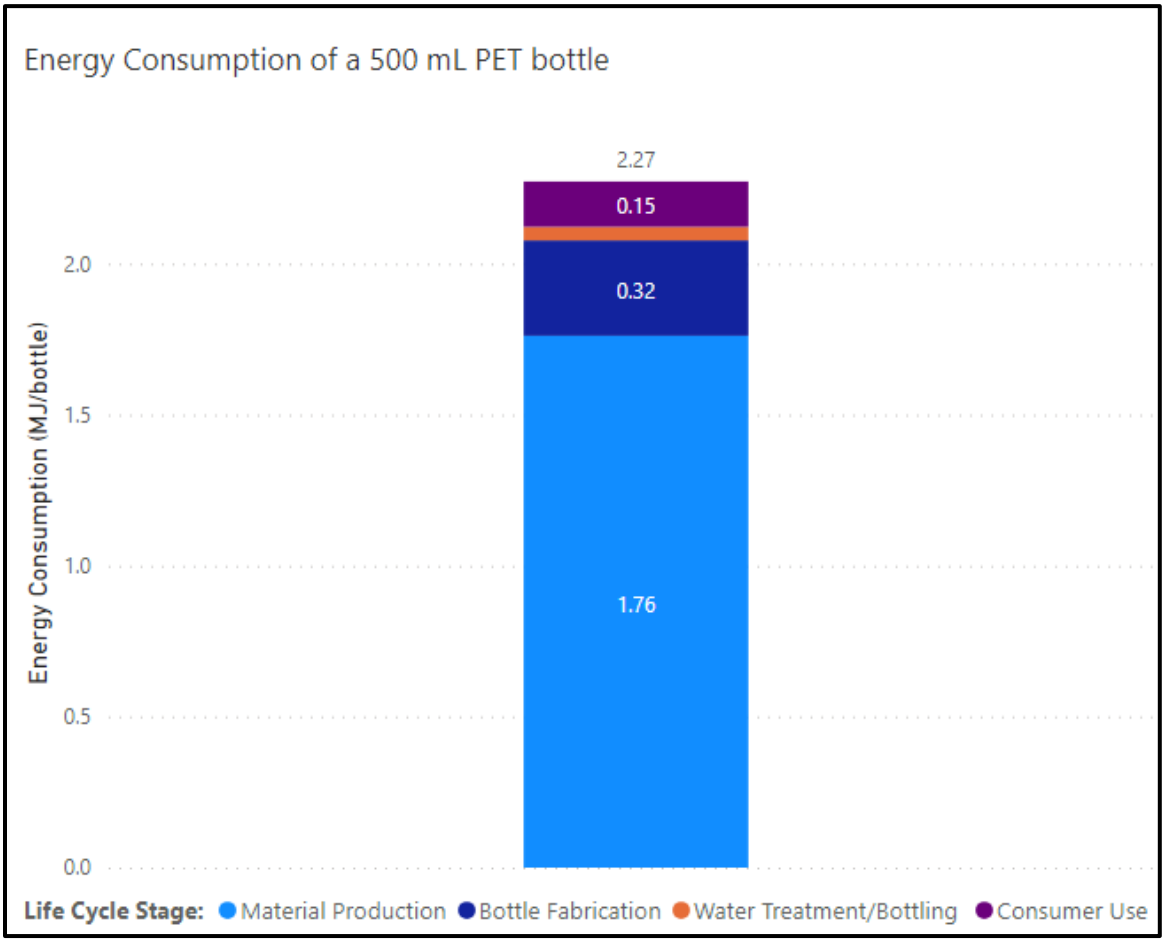
Use

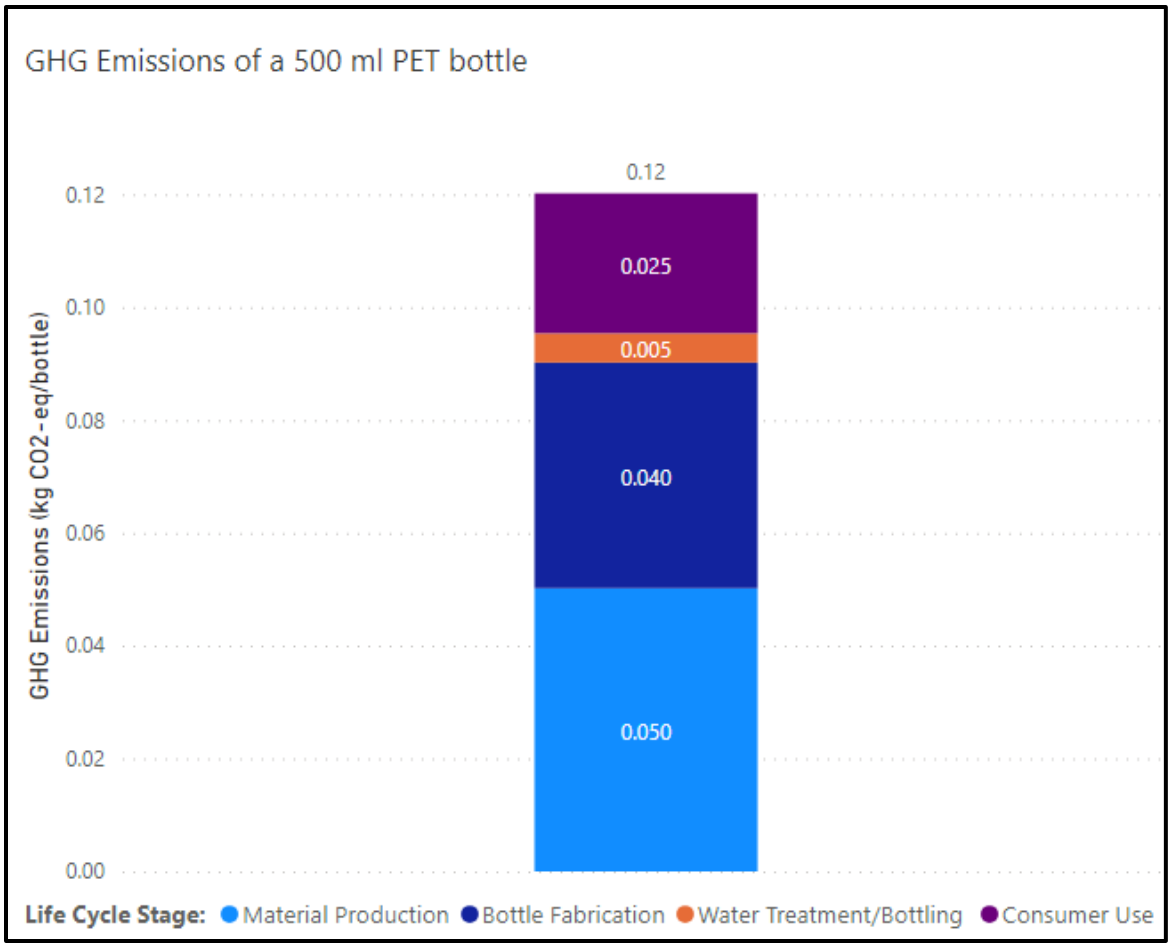
Single-use plastic water bottles are typically disposed after drinking, as they are not intended for reuse due to health concerns[ix]. The potential source of environmental impacts during this phase of the life cycle is chilling the water bottle prior to consumption.

Environmental impact estimates:

Energy consumption: 0.2-0.4 MJ/L of water chilled (refrigerated up to 1 week)[iii vi]

GHG Emissions: 0.0248 kg CO_2-eq/L of water chilled (refrigerated up to 1 week)[vi]





Disposal

PET water bottles are typically disposed of in three ways: recycling, incineration, and landfilling. In the United States, an estimated 29.1% of PET bottles produced were recycled in 2018[x]. The conventional method of PET bottle recycling is mechanical, in which the recycled bottles are shredded, cleaned, and reprocessed into recycled PET pellets to be used in recycled PET water bottles and other products. Plastic bottles are also incinerated for the purpose of energy recovery. Nevertheless, incineration can produce significant GHG emissions. Most bottles are discarded, typically in landfills, for over 69% of plastic container and packaging waste in 2018[x]. However, these water bottles may also find themselves in waterways and pollute the environment. PET plastic bottles take up to 500 years to degrade[xi] and can be a source of plastic pollution and microplastics in drinking water and the environment[xii].

Environmental impact estimates:

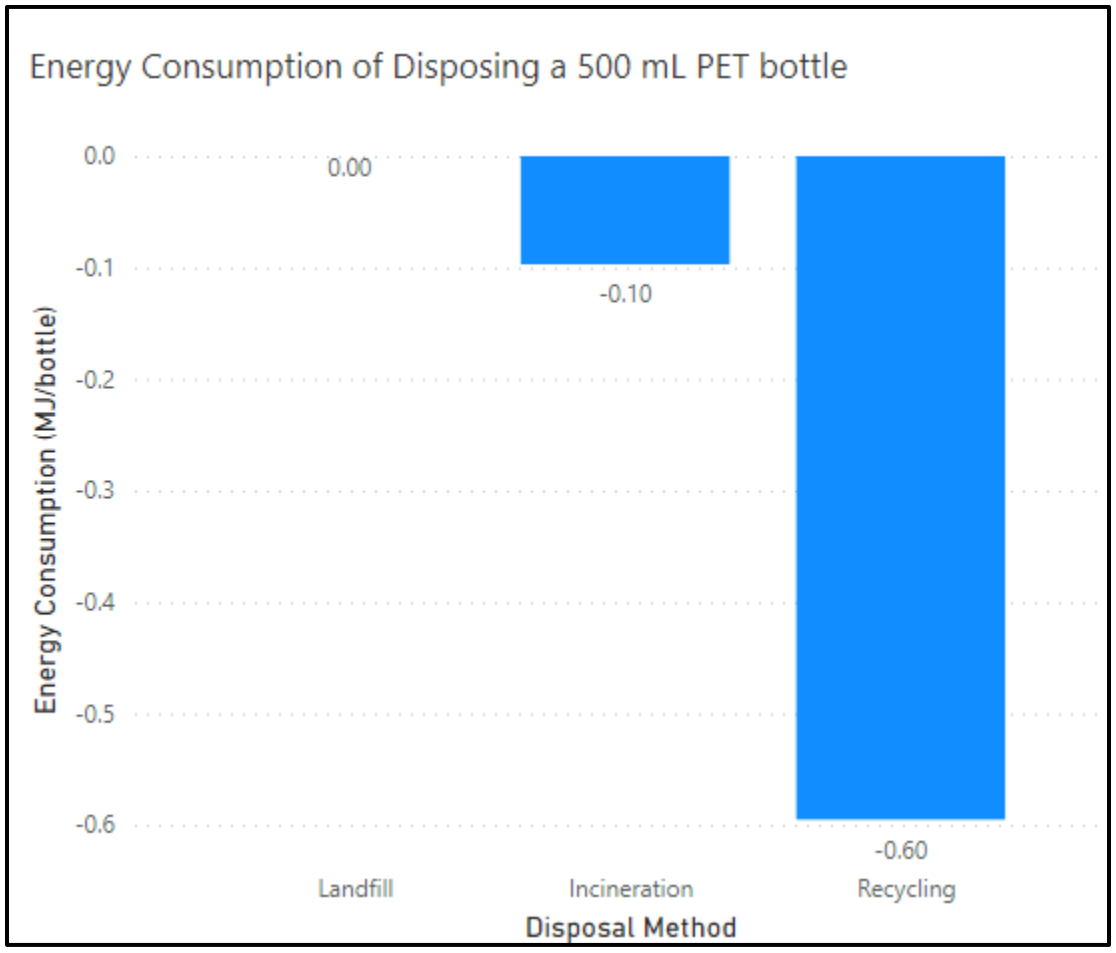
Energy consumption: 0.097 MJ recovered/500 mL bottle incinerated[vii]

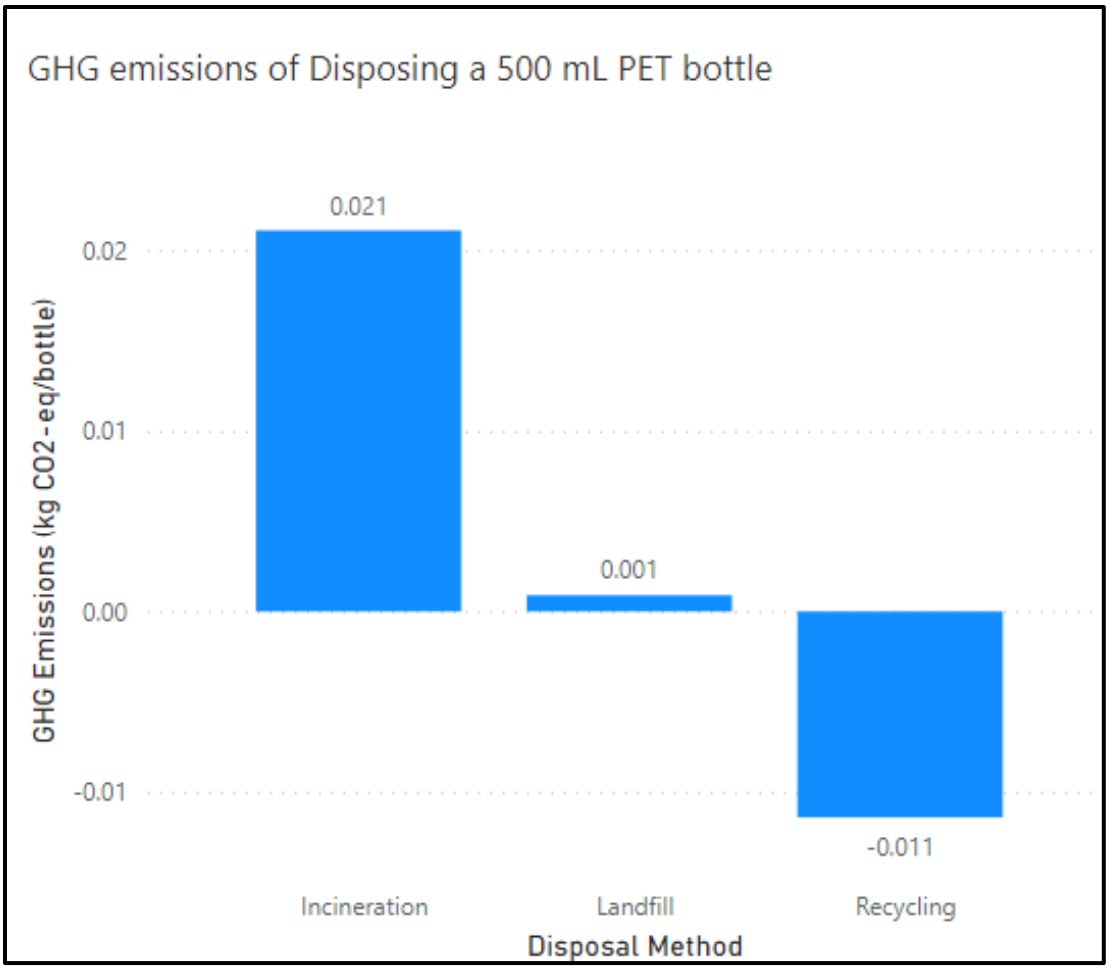
0.595 MJ recovered/500 mL bottle recycled[vii]

GHG emissions: 0.0211 kg CO_2 eq/500 mL bottle incinerated[vii]

0.9 x 10^{-3} kg CO_2 eq/500 mL bottle landfilled[vii]

0.0114 kg CO_2 eq prevented/500 mL bottle recycled[vii]





Transportation

Transportation between and within the stages of the water bottle life cycle above can be done by truck, rail, or ship depending on the specific circumstance. The resulting energy consumption and GHG emissions can vary greatly. Transportation can be a major source of environmental impact in the life cycle of a water bottle in cases where there are large distances between material sources, water sources, manufacturing sites, and/or disposal sites[iii] [vi] [vii].

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