Chemical Recycling of Plastic Waste in Practice: Assessment of Technologies and Economics

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Introduction

- Low recycling rates of plastic waste, combined with high volumes of plastic waste generated (see Fig. 1 for plastic production and recycling data in the US) has raised environmental concerns.
- Limitations in the mechanical recycling of some plastic (i.e., heterogenous plastics, contaminated plastics) has motivated alternative recycling methods such as chemical recycling.
- Chemical recycling encompasses the conversion of polymers into smaller molecules by chemical methods (i.e., thermochemical,) in a way that smaller molecules can be subsequently reprocessed to fuels or plastic.
- Pyrolysis, the method selected for analysis in this study, is a technology used to transform plastics into fuel/oil by reducing long polymer chains of plastics into shorter chain of hydrocarbons at high temperatures, under inert conditions, to produce oil, fuel, and syngas.

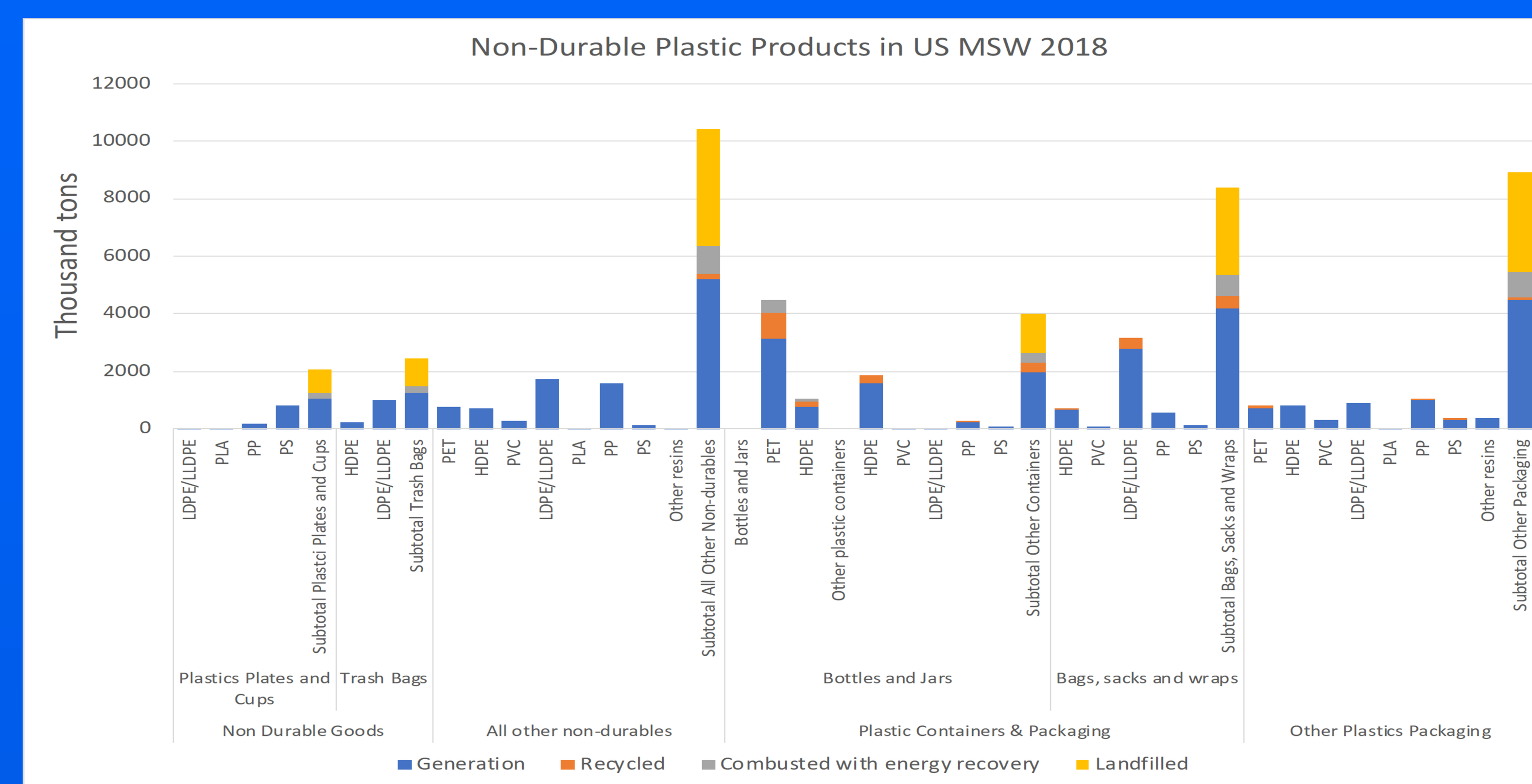

Figure 1: Non-durable plastic products in US waste streams

Method

Techno-Economic Feasibility Assessment of Pyrolysis Process for Plastic Conversion to Oil

- Method of analysis: Selective Design Analysis
- A published process flow diagram (PFD) of a 30 TPD pyrolysis plant with equipment details was selected for analysis; equipment prices were obtained
- Base case Capacity: 30 TPD
- Analysis Accuracy: +/- 30%
- Lang factor method was used to estimate the Total Capital Investment (TCI)
  - (i.e., cost of piping = total equipment cost * 0.3)
- TCI = Direct Fixed Cost (DFC)+ Working Capital (WC)
- DFC = Total plant direct cost + total plant indirect cost + contractors fees and contingency
- Six-tenth rule was used to scale up the plant to 60TPD and 100TPD to obtain scaled up equipment cost (see eq. 1)
- Assumptions
  - Total Capital Investment borrowed and repaid over 20 years with 5% annual discount rate
  - Feedstock: HDPE (10%), LDPE (15%), PP (25%), and PS (50%)
  - Produced fuel gas is used for heat generation, revenue is generated from produced oil, and produced char is landfilled

Table 1: Values of assumptions made (tax rate, Interest rate, plant life) and obtained PCI and OPEX

Parameters used for the Economic Feasibility Assessment	Value
Total Capital Investment ($)	18,228,022
Total Operating Costs or operating expenses (OPEX) (in $/year)	1,973,143
Interest Rate (%)	5
Tax Rate (%)	25
Plant Life (years)	20
Operating Hours/Year	7884 or 90% uptime

Six-tenths rule = Cost(A) / Cost (B) = [Size (A)/Size (B)] ^{index} Eq. 1

Net Present Value (NPV) is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present

$$NPV = \sum_{n=1}^{t} \frac{CF_n}{(1+i)^n} - C_{IC} \quad \text{where} \quad CF_n = \sum B - \sum C$$ Eq. 2

- CF_n : cash flow, which is the difference between revenue (B) and cost (C)
- C_{IC} : overall capital installation costs or Total Capital Investment
- t : lifespan of the investment
- i : discount rate or interest rate

Design Parameters of plastics used for conversion rates

Resin	Ash Content	Volatile	Conversion rate (%)
PET	0.00 0.02	86.83 – 91.75	30
PVC	-	-	30
LDPE	0.00 – 0.04	99.6 – 99.7	65
HDPE	0.18 – 1.40	98.57 – 99.81	65
PP	1.99 – 3.85	95.08 – 97.85	55
PS	0.00	99.50 – 99.63	80

Results & Discussion

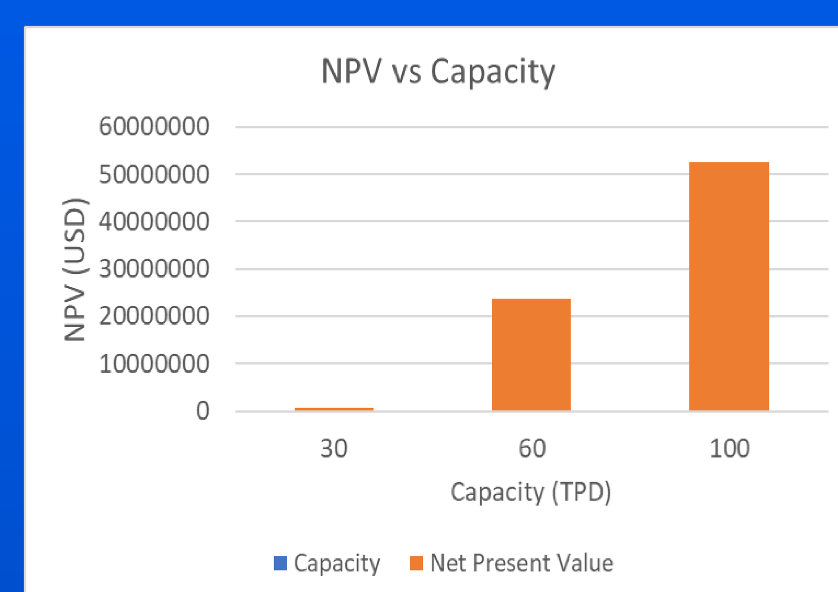

Figure 2: NPV values at 30, 60 and 100 TPD

- The 30 TPD PFD was selected from Sahu et al. and analyzed based on the US market, and scaled up to 60 and 100TPD for feasibility assessment
- The TCI needed for the 30 TPD was $18,228,022, with OPEX of $1,973,143 with revenues of at least $2,966,288/year.
- Returns were not attractive with a NPV of $518,258 over 20 years
- Thus, the plant was scaled up to 60 and 100 TPD for profitability evaluation, with at least a 86% return

Sensitivity Analysis

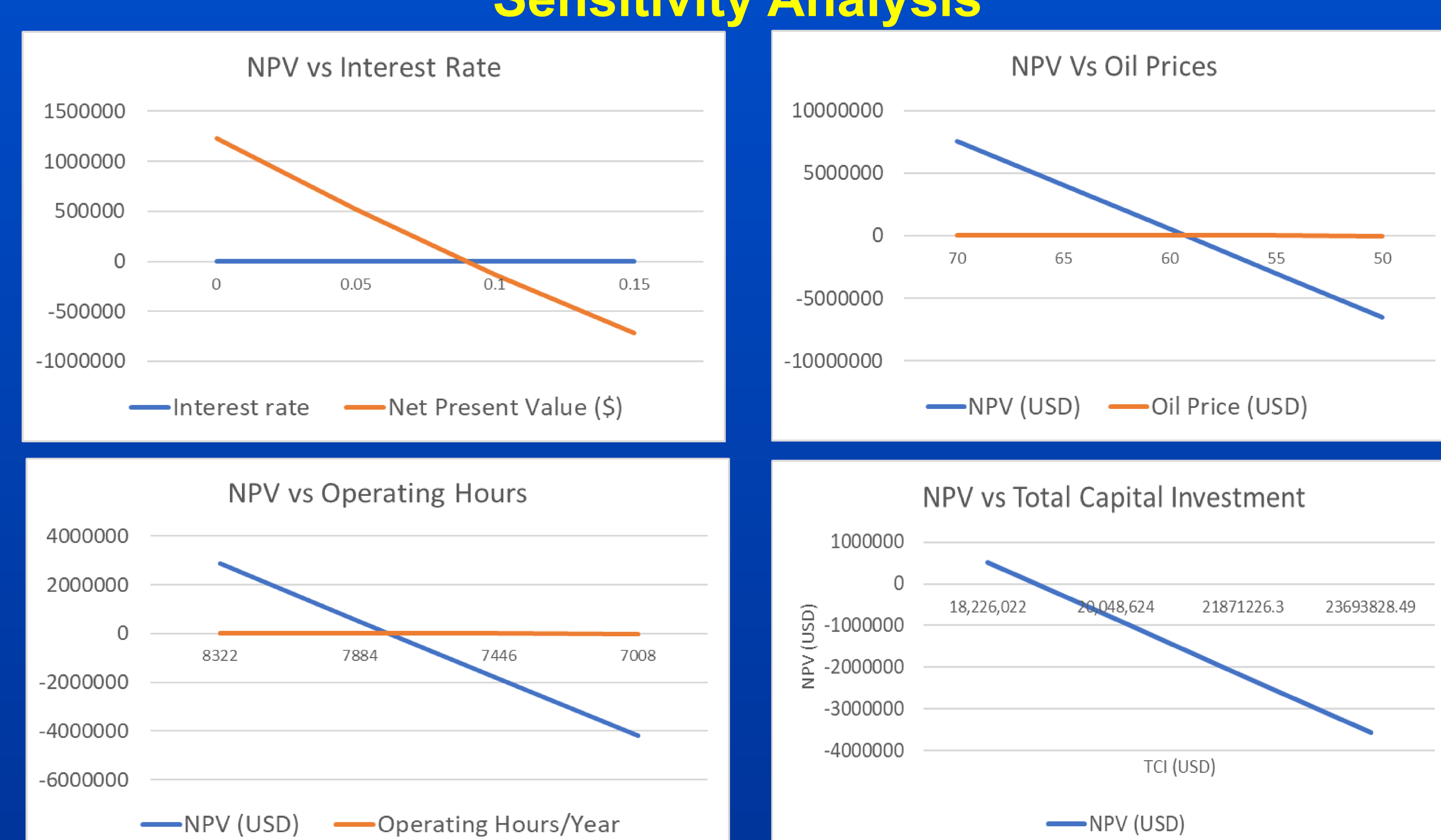

Figure 3: Sensitivity analysis results for the 30 TPD plant

- Sensitivity analysis shows that oil price, operating hours, interest rate, and total capital investment can easily affect the plants profitability at 30TP
- Obtained positive NPV of the base case scenario is $518,2584 or 2.84% return after 20 years, which is extremely low for this types of investments

Conclusions

- An economic feasibility assessment to convert municipal plastic waste to oil using pyrolysis was performed at 30TPD and scaled up to 60 and 100 TPD.
- At 30 TPD, the project is highly sensitive to oil prices, interest rate, operating hours, and it stops being profitable at oil prices < $59 or interest rate > 9% or operating hours < 7788 hours/year. Thus, not economically feasible.
- Scaling up to 60 TPD or higher can be economically feasible with at least 86.2% return in a 20 years period, with a breakeven value of $43, and is less sensitive to price volatility or parameters such as operating time and interest rate compared to the 30 TPD plant.

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