

Pyrolysis System Feasibility Study

For the Port of Port Townsend



Introduction

Project Team & Partners
Project Background

Project Team & Partners

This study was conducted under a Recycling Development Center grant received by the Port from the Washington State Department of Ecology. Tetra Tech, Inc. has completed this study on behalf of the Port of Port Townsend.

This study was completed by the following engineers and technical specialists from Tetra Tech:

Chris Doherty; Keith Henn; Phil Lusk; Chris Noah, P.E.; Anne O'Bradovich; Kimberly Porsche, P.E.; and Al Randall

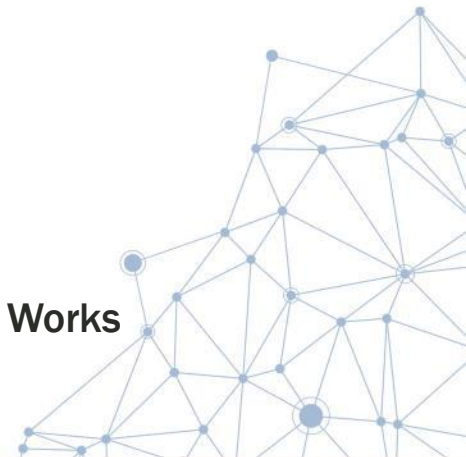
Tetra Tech would like to provide thanks to:

Eron Berg – Executive Director of the Port of Port Townsend

Eric Toews – Deputy Director of the Port of Port Townsend

Pete Langley – Port Foundry

Al Cairns – Solid Waste Manager of Jefferson County Department of Public Works



Background

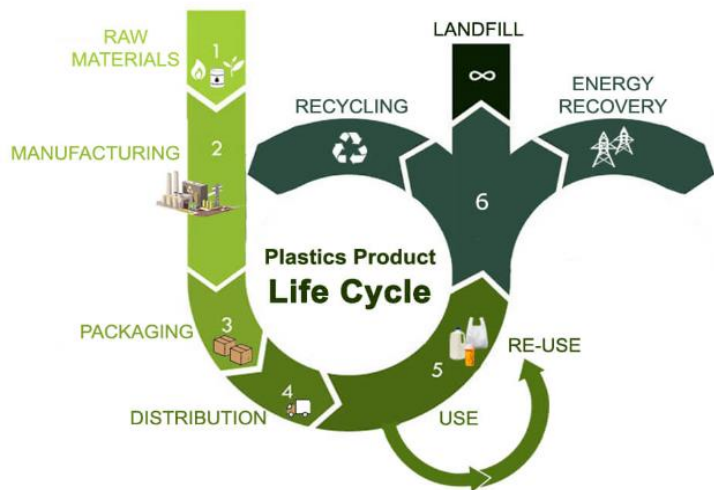
Feasibility Study Goal:

Assess if the conversion of waste plastics via pyrolysis is an effective alternative to the current waste disposal practices. The current practice includes collecting recyclables including plastics in Port Townsend and trucking them to Material Recovery Facility (MRF) in Tacoma, Washington.

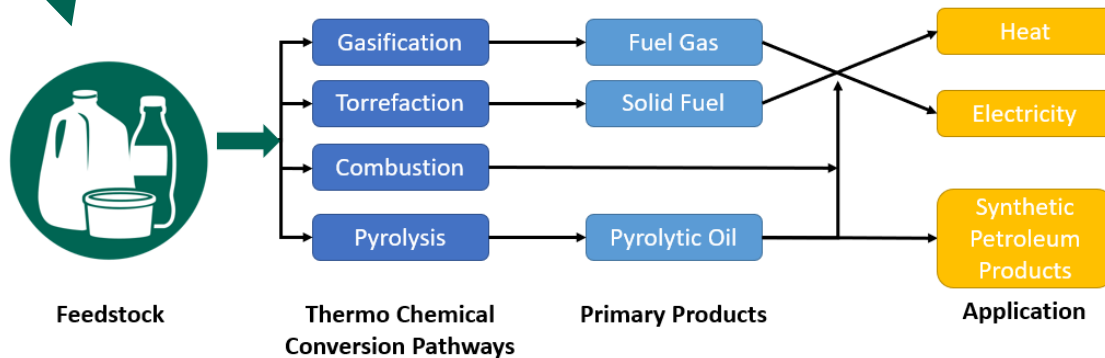
Objectives:

- Identify, analyze, and evaluate available and potential future feedstocks
- Evaluate appropriate pyrolysis technologies and provide recommended option
- Identify offtake market applicability and options for pyrolysis outputs
- Develop an economic assessment for the recommended option
- Develop a preliminary permitting matrix

Background



Thermal Chemical Conversion Pathways



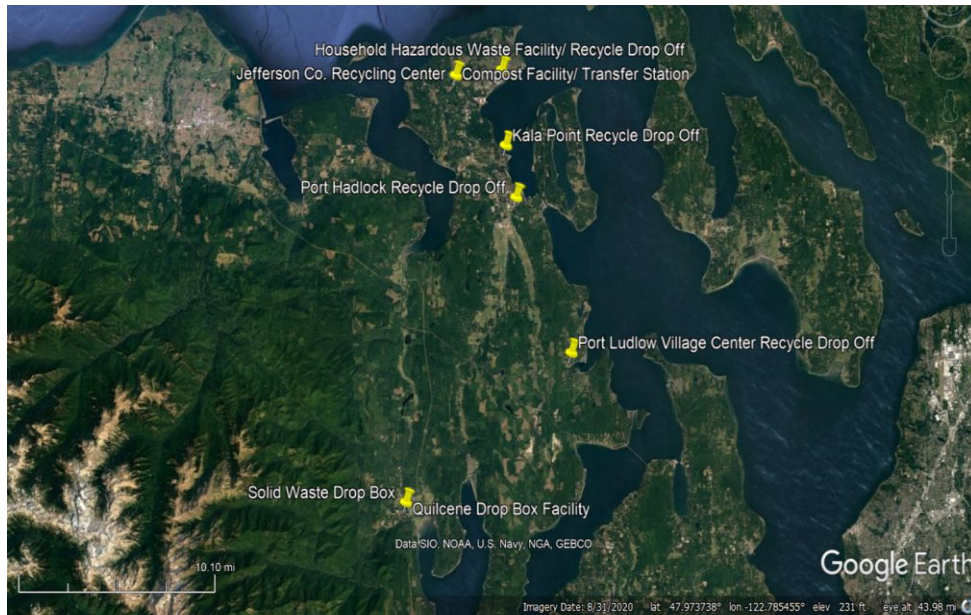
Feedstock Assessment

Existing Feedstock and Recycling Practices

Feedstock Projections

Pyrolysis Scenario Feedstock Assumptions

Existing Feedstock & Recycling Practices



Recycling in Jefferson County
Keep it CLEAN and EMPTY to keep it RECYCLABLE!

Please Place in the TRASH - they will CONTAMINATE the recycling!

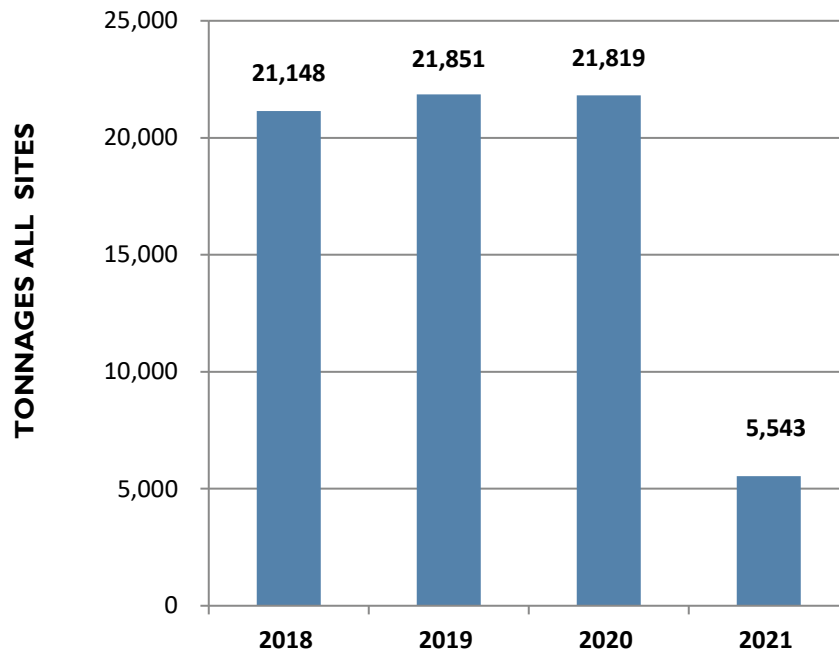
When in doubt, throw it out Place in RECYCLING BINS More info on the back

Place *clean and empty* recyclables loose in bins. *Please*—NO bagged or boxed recyclables in bins.

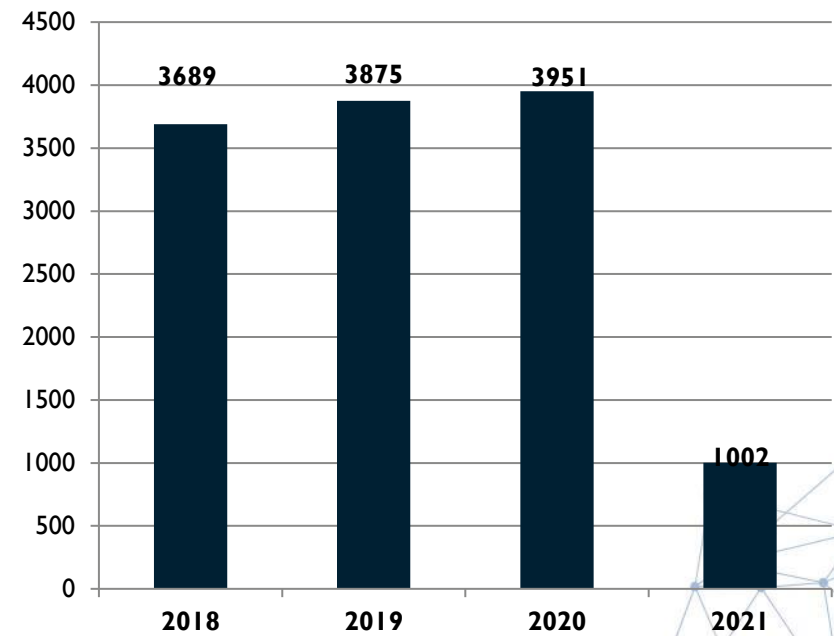
Mixed Paper	Plastic & Cans	Glass	Unwaxed Cardboard
 	 	 <p style="color: red; font-weight: bold;">NO dirty containers!</p>	 <p style="color: red; font-weight: bold;">CLEAN pizza boxes</p>

Existing Feedstock & Recycling Practices

SOLID WASTE TONNAGES BY YEAR

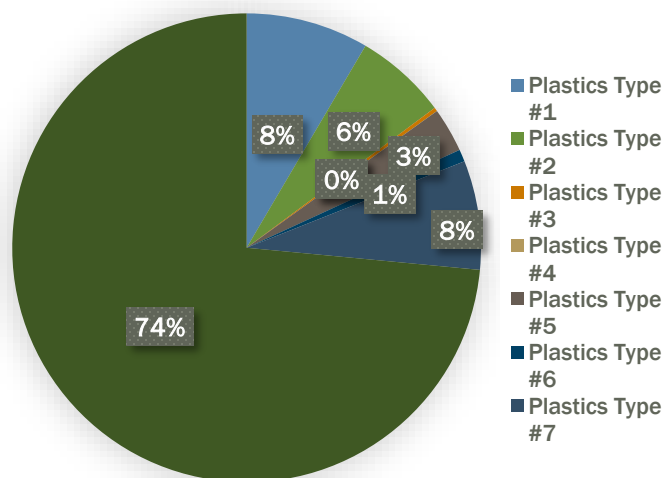









SKOOKUM TONNAGES BY YEAR

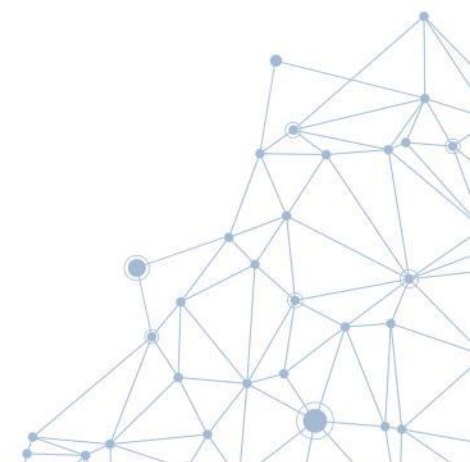


Jefferson County Plastic Waste Characterization

Plastic Waste by Type



 PETE	 HDPE	 PVC	 LDPE	 PP	 PS	 OTHER	OTHER PLASTIC
Polyethylene terephthalate	High-density polyethylene	Polyvinyl chloride	Low-density polyethylene	Polypropylene	Polystyrene	Other plastics including, acrylic, polycarbonate, polyactic fibers, nylon, fiberglass	Other non-marked plastic products
Plastic drink bottles, fruit juice containers, cooking oil bottles	Milk jugs, dairy containers, water jugs, shampoo and washing soap containers	Trays for fruit and sweets, plastic packing (bubble foil) and food foils, some shower curtains & toys	Plastic bottles and containers, shopping bags, highly resistant sacks and wrappings	Plastic packaging, straws, reusable food containers	Rigid packaging, CD cases, vending cups, toys, plastic tableware	Baby bottles, toys, household products, durable plastic products	non-numbered plastic products such as toys, reusable containers, furniture, etc.

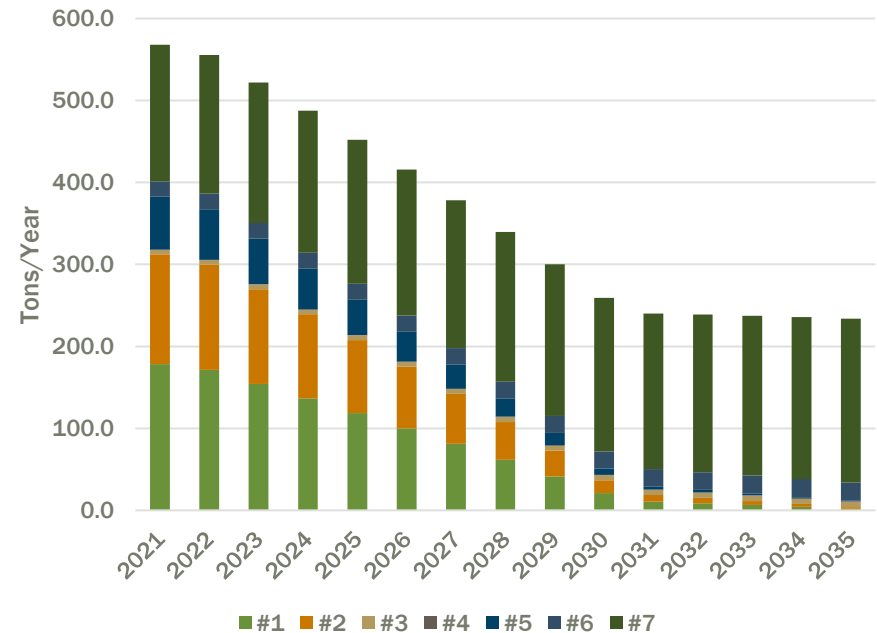


Potential Available Feedstock Projections

Projection of Generated Plastic Waste by Type,
No Change in Single Use Plastic Habits
Jefferson County, WA



Projection of Generated Plastic Waste by Type,
Steady Decline in Single Use Plastic Habits
Jefferson County, WA



Pretreatment System

Overview

Vendors & Sizing

Pretreatment Overview

The goal of pretreatment is to concentrate the valuable feedstock that can be converted and separate it from inert material or other contaminants that cannot be converted.

We reviewed:

- Non-Source Separated (not selected)
- Source Separated (selected)



Source Separated Pretreatment Process Train

Pretreatment Overview

Shredding



Example: Single-shaft shredder (VAZ)

Conveying



Example: Belt conveyor

Vecoplan®

Pyrolysis System Technology

Overview

Vendor Screening

Most Probable Technology

Block Flow Diagram

Products

Pyrolysis Overview

Pyrolysis is defined as the thermal breakdown of higher chain organic molecules (cracking) into smaller organic components. This thermal cracking is done in the absence of oxygen, sometimes with the addition of a catalyst.

The resulting products from the pyrolysis process are:

- Char: Consists of high carbon content solids. Also, any inorganics that might be contained in the waste stream and catalysts that were added and carried through the process.
- Non-condensable Gas: Made up of hydrogen, methane, carbon monoxide and other non-condensable gases. Can be burned similar to natural gas.
- Condensable Liquids: Sometimes referred to as Pyrolysis Oils. Made up of dozens of organic chemicals. Can be exported as-is or separated via distillation or other processing methods.

Pyrolysis Vendor Screening

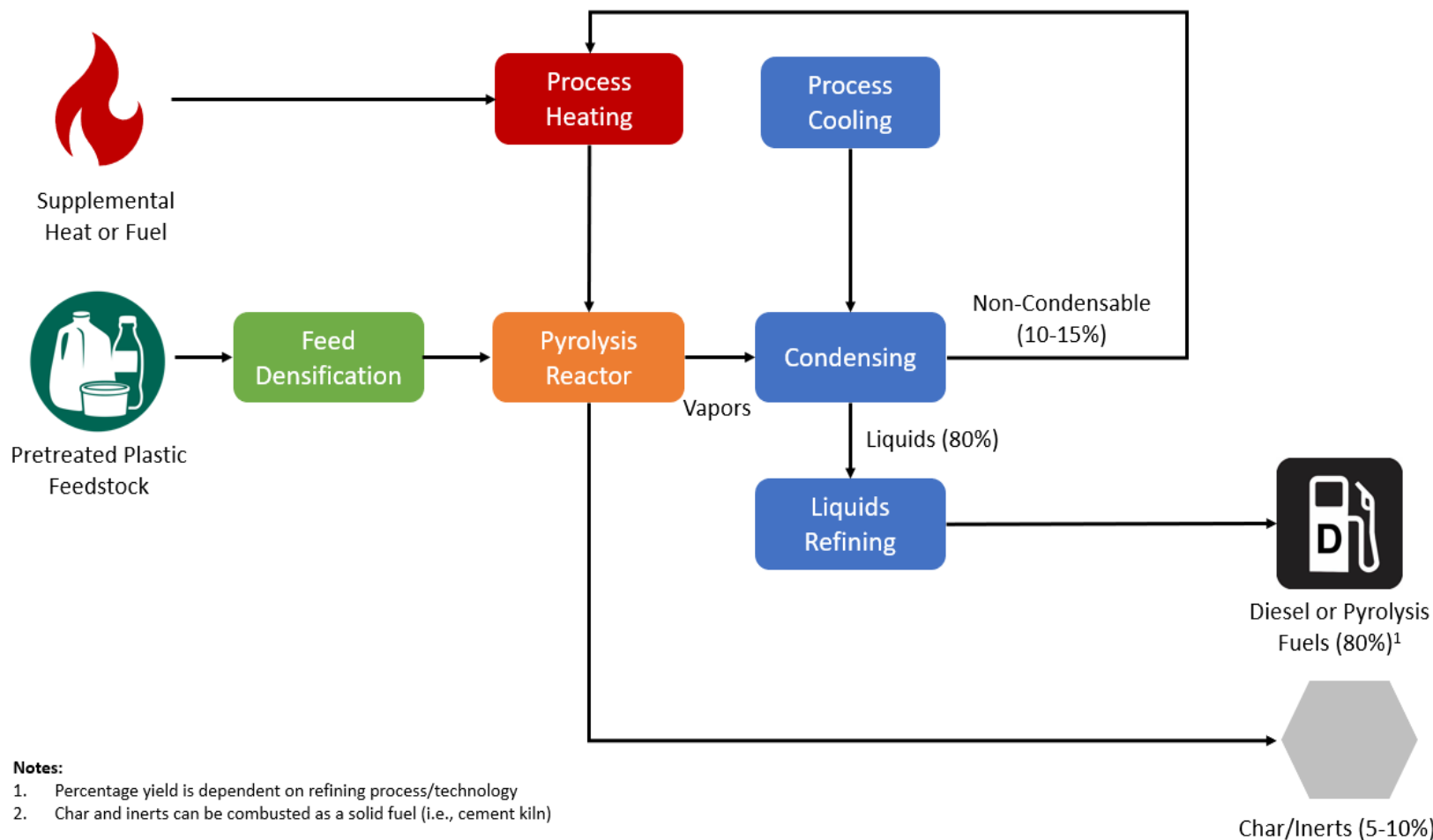
Vendor	Location	Web Page	Response	Evaluated
Agilyx	Tigard, OR	https://www.agilyx.com/	Yes	Yes
Alterra	Akron, OH	https://alterraenergy.com/	Yes	Yes
Braven Environmental	Yonkers, NY	https://bravenenvironmental.com/	No	No
Encina	The Woodlands, TX	https://www.encina.com/	No	No
Enerkem	Edmonton, AB	https://enerkem.com/	Yes	Declined
Nexus Fuels	Atlanta, GA	https://www.nexusfuels.com/	Yes	Yes
PDO Technologies	Brooks, OR	https://www.pdotech.com/	Yes	Yes
Recycling Technologies	Swindon, United Kingdom	https://recyclingtechnologies.co.uk/	Yes	Declined
ThermoChem Recovery International	Baltimore, MD	https://tri-inc.net/pyrolysis/	No	No
Weiss-Linka	Denmark	https://www.weiss2energy.eu/	No	No

PDO Technologies

TECHNOLOGY INFORMATION	1-UNIT - STATIONARY	1 UNIT - MOBILE
Number of batches per Day	4 batches	3 batches
Feedstock Types	Homogenous <i>or</i> Heterogeneous feedstocks Best yield: #2, #4, #5, #6, some #7 Limited/no yield: #1, #3	Homogenous <i>or</i> Heterogeneous feedstocks Best yield: #2, #4, #5, #6, some #7 Limited/no yield: #1, #3
Feedstock preparation requirement	Separation from non target plastics <10% contaminants (dirt, metal, wood). Feedstock Densification to ≥ 20 lbs./ft ³	Separation from non target plastics <10% contaminants (dirt, metal, wood). Feedstock Densification to ≥ 20 lbs./ft ³
Feedstock loading	Continuous batch cartridge processing w/ganged, asynchronous processors	Continuous batch cartridge processing
Single batch size	1,250lbs.	500lbs.
Batch cycle time	5 hours, 30 minutes	3 hours, 15 minutes
Electricity consumption per batch	About 200-250 kwh	About 80-100 kwh
Burner fuel consumption per batch	About 4.1 MMBTU	About 1.7 MMBTU
% yield of plastic-to-fuel	ca. 80%	ca. 80%
Naphtha output per batch	About 50 gallons	About 20 gallons
Diesel output per batch	About 100 gallons	About 40 gallons
Char output per batch	85lbs. (energy content 8,000 BTUs/lb.)	35lbs. (energy content 8,000 BTUs/lb.)
Process emissions	Deminimus	Deminimus



Block Flow Diagram



Products

Pyrolysis Oil

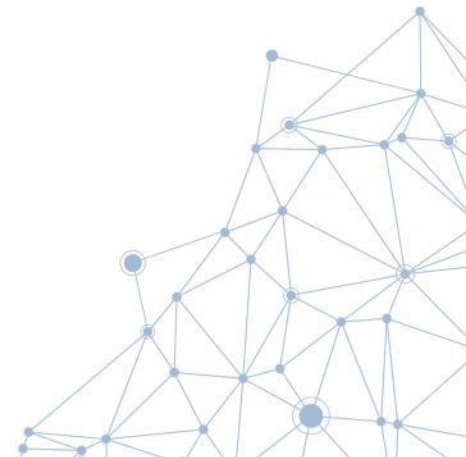
- a. Can be transported to a refinery as-is (sometimes called “Syn-Crude”) and used as a supplement for crude oil. Must be stored and transported at higher temperatures for flowability.
- b. Can be distilled on-site and separated into various cuts that may include the following:
 - a. Waxes and heavy hydrocarbons
 - b. Diesel and gasoline fuel blend stocks
 - c. Naptha products

Non-Condensable Gases

- a. Can be combusted on site to provide heat to the pyrolysis process
- b. Can be combusted on site to provide electricity to the pyrolysis process or for export

Char

- a. Can be refined and marketed as a Carbon Black substitute or other manufacturing constituent
- b. Can be marketed and used as a fuel supplement
- c. Can be disposed of as a solid waste product



Economic Assessment

200 Ton/Year

500 Ton/Year

200 Tons/Year Feedstock Scenario

PROJECT FINANCIAL SCENARIO 200 Tons/Year Process Capacity			
Type	Item	Description	Cost
CAPEX	General	Contract Conditions & General Requirements, Mob/Demob, Site Preparation	\$120,000
CAPEX	Pretreatment Infeed/Outfeed Conveyors	Vecoplan (1) each infeed and outfeed belt conveyors	\$70,000
CAPEX	Pretreatment Shredder	Vecoplan 60-horsepower model VAZ1100XL shredder	\$119,000
CAPEX	PDO Technologies Mobile Unit	PDO Technologies (1) Mobil Unit including; Thermal Processing & Condensing Unit, 2 cartridges, cleaning machine, associated infrastructure, platforms, lifts (as quoted by PDO)	\$1,300,000
CAPEX	Building	Pre-Engineered Building (4,000 SF) including plumbing, HVAC, fixtures and furnishes	\$300,000
CAPEX	Subtotal Direct Capital Costs		\$1,909,000
CAPEX	Permitting & Engineering Fees (15%)		\$190,900
CAPEX	Contingency (20%)		\$381,800
CAPEX	Total Capital Costs		\$2,481,700
OPEX	Pretreatment System	Annual Operating Cost (power usage, maintenance, consumables, manual sorting labor)	\$67,700
OPEX	PDO Technologies Stationary Unit	Annual Operating Cost (as quoted by PDO Technologies)	\$154,896
OPEX	Total Operational Costs		\$222,596
REVENUE	Pyrolysis Oil	55,500 gallons produced per year (200 tons/year plastics processed); fuel price of \$2.50/Gallon	\$138,750
REVENUE	Cost Avoidance	Tipping Fees at Roosevelt Regional Landfill avoided for (200 tons/year)	\$14,330

500 Tons/Year Feedstock Scenario

PROJECT FINANCIAL SCENARIO 500 Tons/Year Process Capacity			
Type	Item	Description	Cost
CAPEX	General	Contract Conditions & General Requirements, Mob/Demob, Site Preparation	\$150,000
CAPEX	Pretreatment Infeed/Outfeed Conveyors	Vecoplan (1) each infeed and outfeed belt conveyors	\$70,000
CAPEX	Pretreatment Shredder	Vecoplan 60-horsepower model VAZ1100XL shredder	\$119,000
CAPEX	PDO Technologies Stationary Unit	PDO Technologies (1) Stationary Unit including; Thermal Processing & Condensing Unit, 2 cartridges, cleaning machine, associated infrastructure, platforms, lifts (as quoted by PDO)	\$975,000
CAPEX	Building	Pre-Engineered Building (5,000 SF) including plumbing, HVAC, fixtures and furnishes	\$375,000
CAPEX	Subtotal Direct Capital Costs		\$1,689,000
CAPEX	Permitting & Engineering Fees (15%)		\$168,900
CAPEX	Contingency (20%)		\$337,800
CAPEX	Total Capital Costs		\$2,195,700
OPEX	Pretreatment System	Annual Operating Cost (power usage, maintenance, consumables, manual sorting labor)	\$71,600
OPEX	PDO Technologies Stationary Unit	Annual Operating Cost (assume 75% quoted by PDO Technologies due to less processing)	\$207,675
OPEX	Total Operational Costs		\$279,275
REVENUE	Pyrolysis Oil	111,420 gallons produced per year (500 tons/year plastics processed); fuel price of \$2.50/Gallon	\$278,550
REVENUE	Cost Avoidance	Tipping Fees at Roosevelt Regional Landfill avoided for (500 tons/year)	\$35,825

Conclusions & Recommendations

Conclusions

Most Probable Technology: PDO Technologies

Their technology is feedstock flexible, able to shift products, and allows for greater operational flexibility due to the batch operation of the pyrolysis reactor.

System Sizing:

- Maximum Size 500 Tons/Year – PDO Technologies Single Stationary Unit
- Minimum Size 200 Tons/Year – PDO Technologies Mobile Unit

System Economics:

- 500 Tons/Year – PDO Technologies Single Stationary Unit
 - Total project capital and operational costs is approximately \$2.5M and \$223K/year
 - Estimated revenue is \$138K/year from sale of 55,500 gallons of fuel at \$2.50/gallon
 - A minimum tip fee of \$0.70/lb is required to break even
- 200 Tons/Year – PDO Technologies Mobile Unit
 - Total project capital and operational costs is approximately \$2.2M and \$280K/year
 - Estimated revenue is \$278K/year from sale of 111,420 gallons of fuel at \$2.50/gallon
 - A minimum tip fee of \$0.21/lb is required to break even

Limitations on Feedstock Sourcing

- Curbside services within the City of Port Townsend is currently a three-bin system which is contracted. It is unlikely that the provider would provide a separate bin for plastics.
- Curbside services for unincorporated Jefferson County are by subscription with a private sector hauler. This hauler is unlikely to adjust service to provide a separate bin for plastics.
- Drop box services have high contamination rates (up to 30%) mostly stemming from plastics.
- Public Works is not presently interested in financing or siting on County property a MRF to separate plastics from MSW
- As state and federal legislative action is trending towards reducing the production and consumption of single use plastics, Jefferson County has been considering discontinuation of plastic collection as part of its services

Recommendations

- Contact PDO Technologies for a more detailed discussion/presentation of their process considering the now known parameters of the Port of Port Townsend application. The discussion should include possible financing options and potential off-take scenarios.
- Confirm the feasibility of implementing a plastics-only source separation program (inclusion of another collection bin)
- Conduct a waste composition study to better quantify the type and composition of plastic feedstock available for a pyrolysis project
- Investigate the feasibility of combining the Port's waste plastics with the waste plastic from the rest of Jefferson County to support a larger scale pyrolysis project.
- Perform a local/regional market assessment to quantify the market potential and pricing for pyrolysis products including the char as a manufacturing additive or solid fuel replacement, the syn-crude as a diesel fuel blendstock, and the naptha and heavy hydrocarbons as petrochemical additives.