ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Economic Analysis of the Pacific Garbage Patch

Application of Economics, Sustainability and Scenario Analysis

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Abstract:

The purpose of this paper is to perform an economic analysis of multiple scenarios involving the collection of plastic from the Great Pacific Garbage Patch. A variety of scenarios were considered and data from ongoing research was used to develop assumptions regarding the size of the patch, economic benefit to harvest the plastic and potential subsidies to make the process feasible. This paper considers several factors such as ownership, responsibility, the problem, details of the garbage patch, model for the collection methodology, and an economic analysis.

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Introduction

Little by little, plastic appears to be playing an increasingly dominant role in regards to ocean health. Organic polymers had been used for limited applications through the 18th century until 1909 when Leo Baekland is credited with having developed the first fully synthetic polymer known as Bakelite [1]. Chemists around the world quickly followed Baekland's discovery to develop unique synthetic polymers such as polyvinyl chloride, polystyrene, and nylon. Following the Second World War, industry was saturated with synthetic polymers [2]. Consumers continue to use and discard plastic products and packaging typically with little regard for the fact that synthetic polymers do not naturally break down at the molecular level. Although exposure to naturally-occurring ultraviolet radiation and a host of kinetic forces continually break plastics into smaller fragments, these fragments remain unchanged at their most basic molecular level. Either through inadvertent waste management failure, littering, or a host of other feasible causes, plastic fragments get picked up by the water cycle where it is eventually washed into moving water bodies that ultimately feed into the oceans. Once in the ocean, jet currents and other meteorological factors eventually drift material into what is known as the North Pacific Gyre where "trade winds and circular currents … tend to keep whatever meanders into it without self-propulsion for months, years, even decades at a time [3]." Plastic fragments continue to physically break down at which point the toxic polymers are introduced into the lower tiers of the food chain eventually resulting in human consumption. Although the potential impact to the environment and to humans in particular could be discussed in great detail, this paper will make the assumption that this is a scenario demanding attention and in turn will focus on possible solutions. This will open the door for an economic analysis of the Great Pacific Garbage Patch to explore a variety of questions such as:

- Who is responsible for cleaning the Great Pacific Garbage Patch?
- What is the composition and resultant value of the Great Pacific Garbage Patch?
- Is there an economic benefit to harvesting the plastic in the North Pacific Gyre?
- If not, could potential subsidies close the gap sufficiently to make it economically feasible?
- If so, what nations/enterprises would be able and/or willing to provide such incentives?

Ownership

The discussion of ocean ownership is a complex matter. Although the United Nations Conference on the Law of the Sea has set forth guidelines for oceanic jurisdictional boundaries, they have yet to be formally ratified since first meeting on the matter in 1958 [4]. Regardless, most nations adhere to the established guidelines of territorial seas extending 12 nautical miles off of the shoreline. Additionally, an Exclusive Economic Zone extends to 200 nautical miles, which allows each respective country exclusive rights to the "economic exploitation and environmental quality of their EEZ. [4]"

Although this information is helpful in grasping the rights and responsibilities of a nation within this buffer zone, the matter of the high seas is a different case. The North Pacific Gyre lies in the high seas, which are subject to international law. The rights and responsibilities dictated by international laws guiding usage of the high seas means that all nations have a right to freely navigate their vessels within this area [5]. The other side of this coin is that no single nation has responsibility for any particular region of the high seas. If a valuable economic resource is discovered on the high seas, no single nation has exclusive rights to that resource. On the other hand, if there were a scenario that is found to require economic investment, the onus for such an investment would be difficult to place at the foot of a single entity.

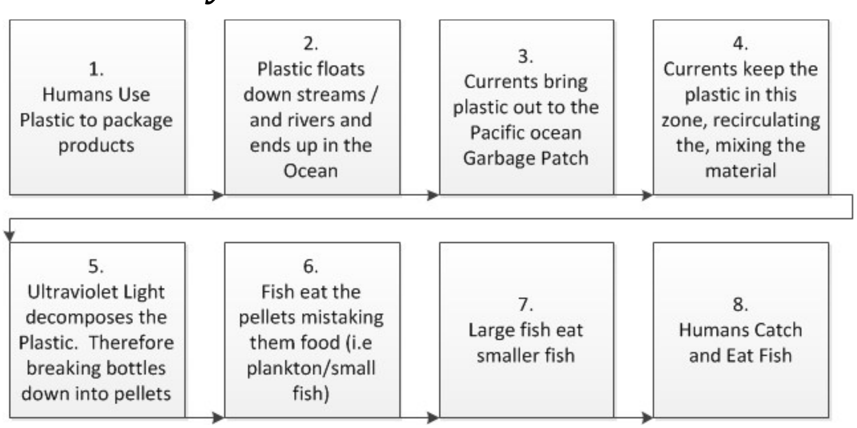
Responsibility

Responsibility for the garbage patch is an important matter to understand in the pursuit of establishing subsidies or other forms of government investment. This requires looking into the source of the pollutants. In the case of the Great Pacific Garbage Patch, unsubstantiated estimates have claimed approximately 80% of the pollutants are from land-based sources whereas 20% come directly from ocean traffic [6]. Under this scenario, nearly any nation on the globe could be a potential contributor as the high seas allow for the free navigation of any vessels. More intensive studies have tracked pollutants from both the west coast of North America [6] and the eastern shores of Asia [7]. Although this may be a valuable first step in identifying responsibility for the patch, it is by no means exhaustive and simply shows the extent to which this scenario has been wrought by a collective global effort. Rather than being portrayed as an issue for a single nation, there is enough evidence to suggest that all nations share a responsibility for ocean health.

The Problem

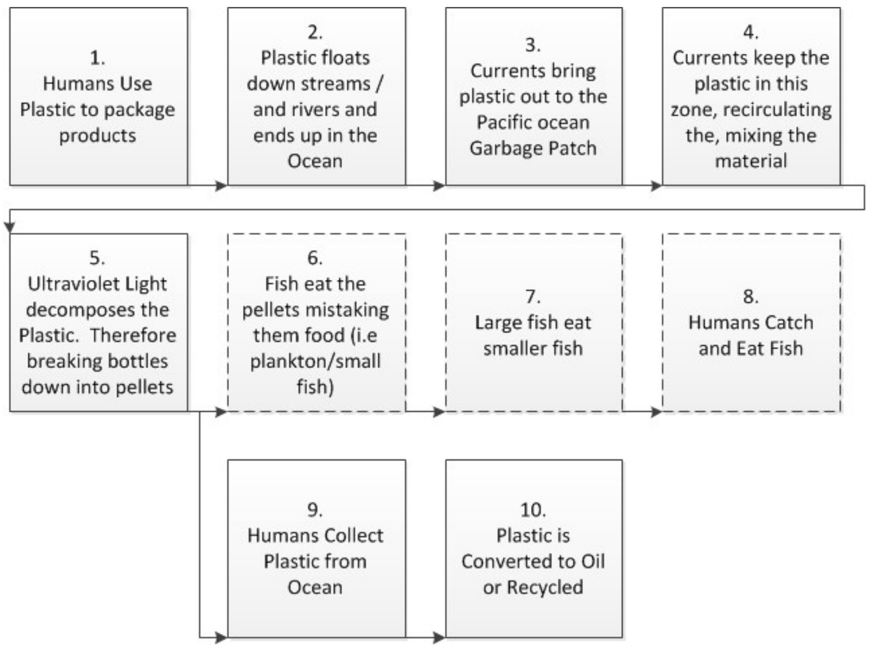
The problem that is faced can be understood by the creating a current reality tree that illustrates what happens to plastic as it is brought into the environment of the ocean. Figure 1 illustrates the lifecycle process that plastic experiences in the ocean environment [8].

Figure 1– Current Reality Tree



As indicated by the above figure plastic is broken down and weakened by ultraviolet light. This breaking down essentially converts the plastic from larger pieces into continuously smaller pieces. The currents and movement of the water continuously mixes the material so that Ultraviolet light breaks down the entire mass. The root cause of the issue is the exposure of the plastic material to the environment in the first place, however this paper will look at the process from the perspective of interjecting a remedy of collecting the plastic as it is introduced to therefore reduce the impacts on the environment. The future reality tree in Figure 2 identifies and illustrates how this interjection impacts the current

Figure 2– Future Reality Tree



In the diagram steps 6, 7, and 8 are effectively reduced, however they are not eliminated entirely. For this boundary on the box was changed to a dashed line. The purpose of this analysis is to explore the financial models and feasibility of collecting plastic from the ocean and determine whether the business case can support the model.

Chemical Make-up

A concern for the method of collection that is being proposed in the identification of the plastic that is present in the Garbage Patch. There have however been several studies of these materials. As Rios et al identified in the paper Quantitation of persistent organic pollutants adsorbed on plastic debris from the Northern Pacific Gyre's ''eastern garbage patch'' the make-up of the contents is primarily Polyethylene and polypropylene [9]. As indicated by Figures 3 and 4 these materials are similar. Chemically these materials are both in the Polyolefin family and can be blended together and commercially sold as a TPO or a Thermoplastic Olefin.

Figure 3 – Polyethylene

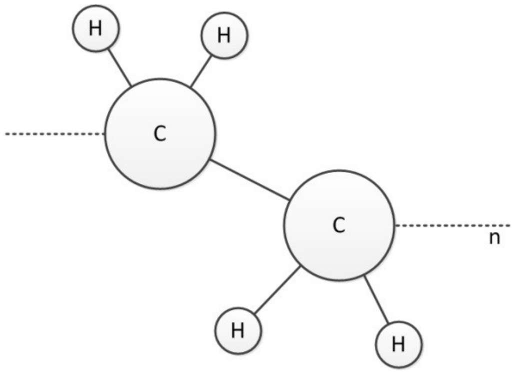
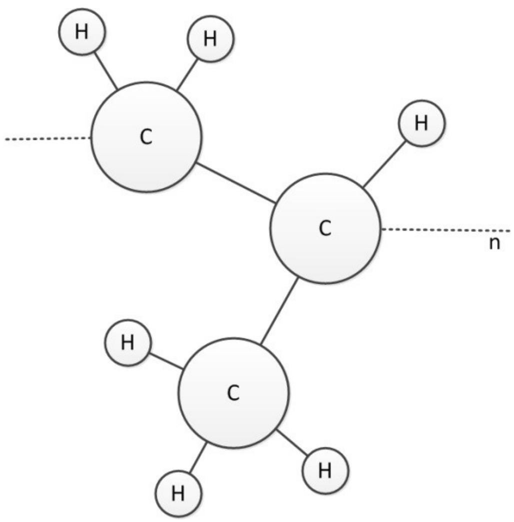


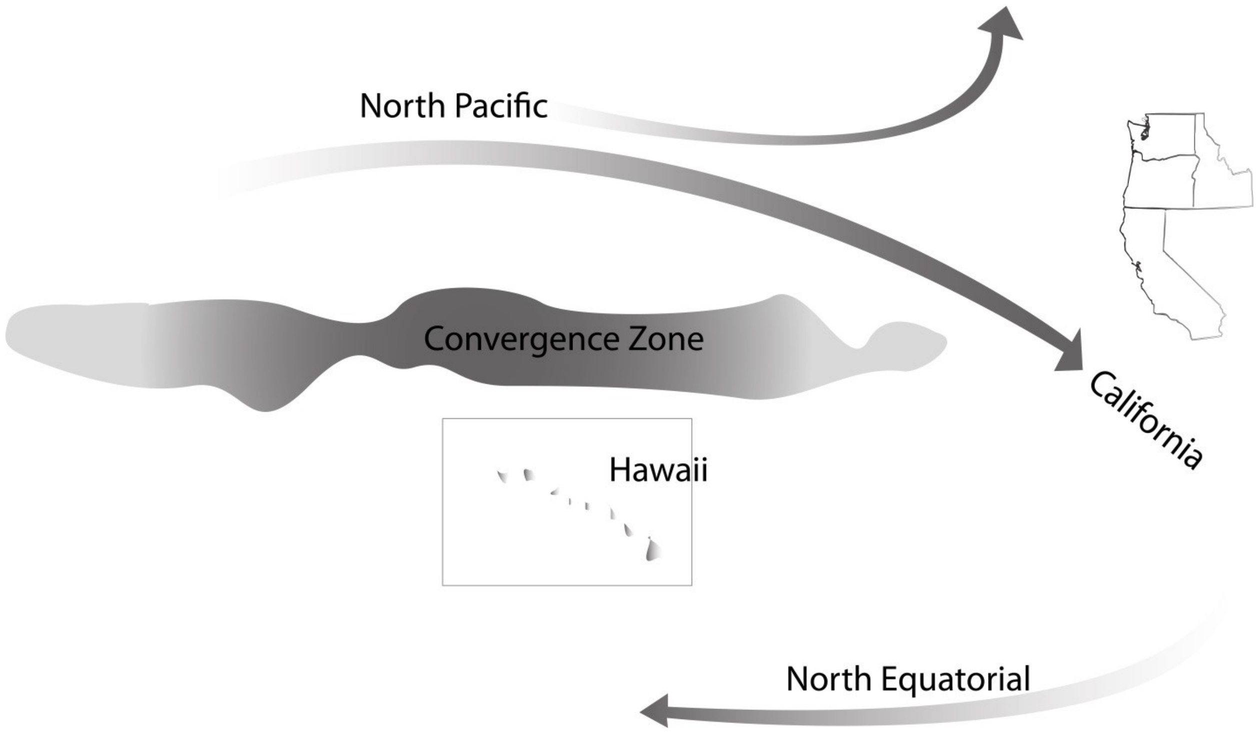
Figure 4 – Polypropylene



Size of the Area and Location

The area in the ocean that is being proposed for collection is approximately 3.5-million-square-kilometers [10]. Additionally this zone grows by over 20 tons of plastic garbage per year [9]. Although the patch clearly is not regarded as a static object floating in a single location, the patch is generally believed to be located between 135°W and 155°W, and 35°N and 42°N [11]. In simple terms, this defines a large area approximately half way between the western coast of the US and the Hawaiian Islands. The centroid of this area was used as the destination coordinates for collection as an approximation for an average trip.

Figure 5 –Location

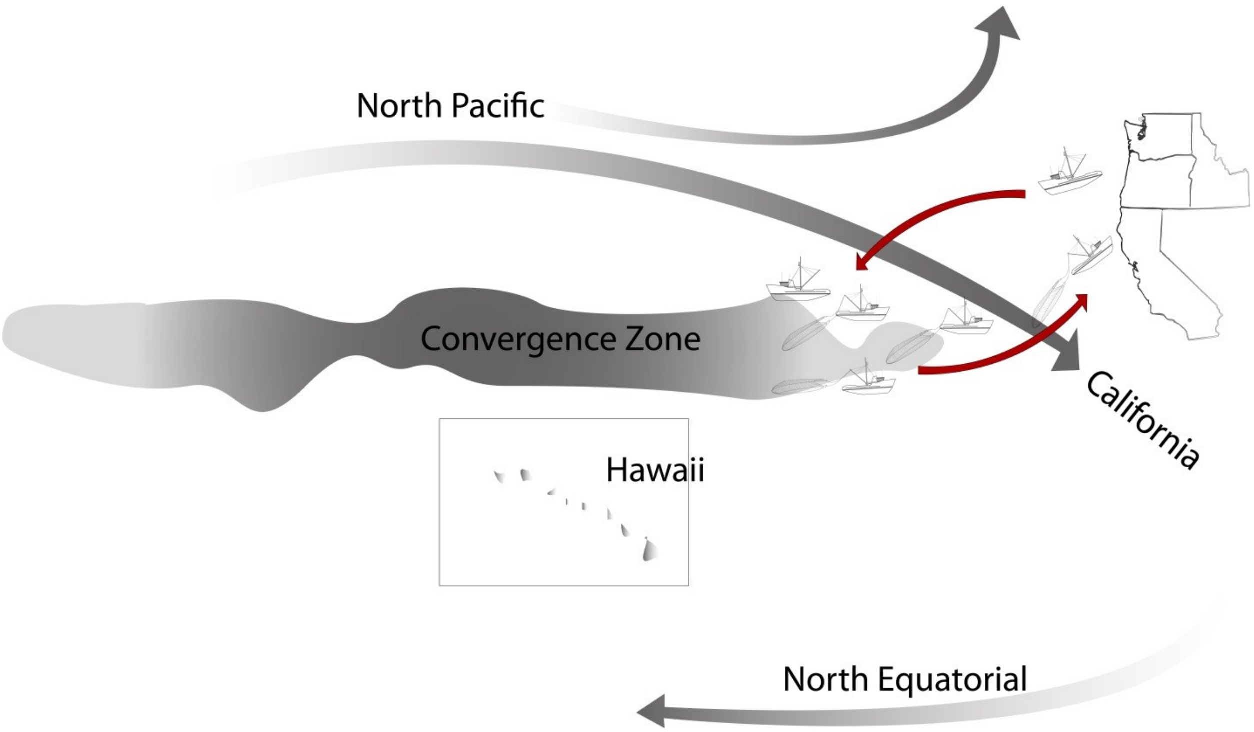


Model for the Collection

The proposed solution for the collection of the plastic in the Pacific Ocean garbage patch involves taking a boat from the Puget sound in Seattle to the location identified in the in the previous section. At this location the plastic garbage would be collected using traditional shrimping techniques where a net would be cast into the water and pulled by the boat. This can be done behind a variety of different types of boats including diesel-powered boats or wind/sail powered which would save on the cost of fuel, which will be considered in the calculations for this project [12]. These boats all have varying costs associated with their maintenance, operation, fuel and crew size.

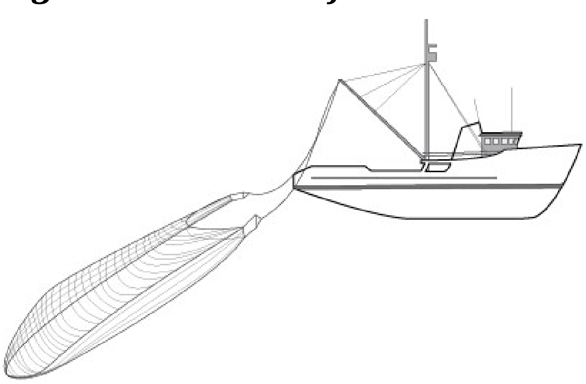
The shrimping boat technique uses nets combined with otter boards which allow for the operators to set the height of the nets thus allowing them to effectively gather the plastic at the proper depth. Using this process the plastic would be collected and then pulled onto the boat for storage and transport back to the port. These otter boards also have a built in release for live animals allowing them to swim out and not be trapped in the net thus reducing the potential negative impact to the wildlife [13]. Figure 6 illustrates the method for collection that is being proposed.

Figure 6 –Collection



The use of a cast or throw net with a fine spacing would need to be utilized in order to collect the plastic particles that are being analyzed. The net can be connected to the boat to allow for towing or trolling through the water during the collection process. This general concept is illustrated in Figure 7.

Figure 7 – Method of Collection



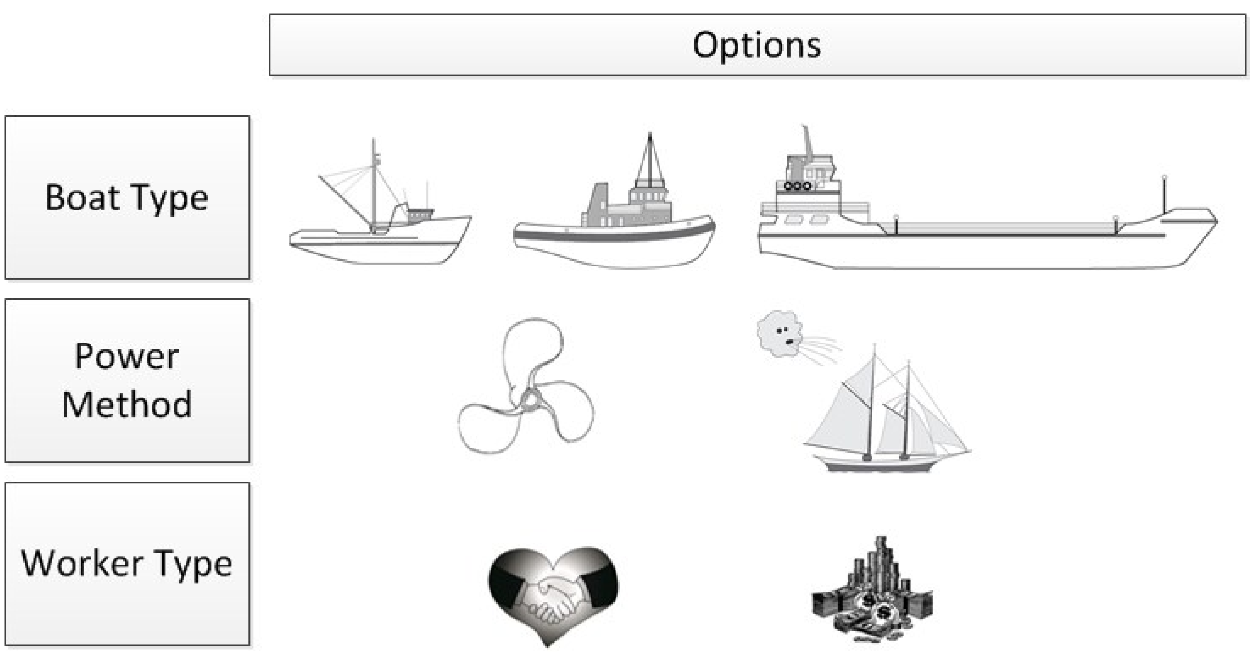
Collection Analysis

When constructing different scenarios to collect the plastic the first variable as seen in Table 1 is selecting the boat. The boats are classified based on size ranging from less than 40 foot (commercial fishing boat), to 40-80 foot (crabbing vessel), and 80-120 foot (commercial crabbing rigs). These boats will vary based on cargo capacity and operating costs (See Appendix A). The next option in Table 1 is the propulsion method, the traditional fishing boat uses diesel engines to power it but for this project wind power will also be analyzed. Using wind power would allow for the plastic collection to be done for a potentially lower cost, basically the savings in diesel. The final variable would be the gathering of the work force. Appendix A shows the cost of having a crew to operate the boat and collect the plastic but the other alternative would be to get volunteers who are interested in helping out the environment who are willing to work for free. Using all these different alternatives for potential ways of collecting the plastic will allow for the high cost deal braking or deal making factors to be identified. This will be beneficial if this project were to ever be pursued by an investor.

In order to fully develop cost tables for the various scenarios, several assumptions were made. As stated earlier, the distance of a one way trip was determined to be the distance between the approximate centroid of the patch at 148°W 38.5°N to a port in either Portland, OR or Seattle, WA. For the cost of fuel, it was assumed that an operation such as this would have access to fuel at near wholesale prices assuming economy of scale. Using the 1-year forecast of \$105/barrel [14] plus an additional 10% for miscellaneous costs, a cost of \$2.75/gal of diesel was used.

Since specific collection methods have not been identified or developed yet, the harvest rate was developed by taking a rough approximation of the mass density of the surface debris of 11.27 lbs./km^2 and further assuming that a ship's capacity to collect debris was directly related to its size. Assuming a ship could accommodate a screening device with a width equal to the ship's length, and that approximately 90% of the debris is below the surface, the cruising rate was used to find the amount of time to accumulate 200 pounds by skimming the surface [15]. The assumptions and full formulas for cost can be found in Appendix A.

Table 1 – Scenarios



Reuse Options

There are two methods of reuse of the material identified after the collection of the plastic material is complete. The first is the reuse of the plastic, and the second is conversion of the material to an oil state. Each of the options will be discussed individually below.

The first option involves the reuse the plastic which is accomplished by compound the reclaimed plastic and converting the flakes to a material that would be commercially useful in an injection molding machine. For this method one ton of plastic would be required as an input and the extruder rate would need to be included at a rate of $220 to $280 per lb. The extruder rate was determined by obtaining a quote from a compounder as to the market rate for extruding and compounding material [16].

The second option involves converting the plastic material to oil. This method is achieved by heating the plastics to vapor, trap the vapor, and condense the gas to liquid. The equipment that would be used for this was described in the Clean Technical article *Award-Winning Inventor Makes Fuel from Plastic Bags*. In the article it was identified that the system uses 1 kg of plastic and 1 kW of electricity to convert the plastic to oil [17]. For comparison purposes 1 ton of plastic would cost 93.44 to convert to oil and would use approximately 907 KW of energy. For the cost of electricity $.103 was used, as this is the commercial pricing listed by the Energy Information Administration [18]. The output from the process would be 907.19 Liters of Oil which is 5.7 barrels of oil.

Reuse Option Pricing

After the plastic is converted in the options identified above, the material will need to be sold in order to determine the business case. Therefore the market rates for the output mediums need to be established. To determine the market rate for plastic two sources were used for benchmark Public Research and Plastic News [19] [20]. Tables 2 and 3 identify the resin prices for olefin based materials.

Table 2 – Public Research Resin Sale Prices

Resin/Grade	Low	High	Average
LDPE - Film	$0.65	$0.85	$0.75
LLDPE - Film	$0.67	$0.75	$0.71
HDPE - Blow Mold	$0.63	$0.71	$0.67
PP - Homo	$0.71	$0.87	$0.79
LDPE - Inj	$0.67	$0.78	$0.73
PP Copo	$0.74	$0.89	$0.82
HMWPE - Film	$0.72	$0.76	$0.74
HDPE - Inj	$0.61	$0.77	$0.69
LLDPE - Inj	$0.70	$0.81	$0.75

Table 3– Plastic News Resin Sale Prices

Resin/Grade	Low	High	Average
PP - Industrial Flakes	$0.63	$0.67	$0.65
PP - Industrial Pellets	$0.74	$0.78	$0.76
HDPE - Post Consumer	$0.57	$0.67	$0.62
HDPE - Post Consumer Pellets	$0.65	$0.69	$0.67
HDPE - Mixed Color Flake	$0.47	$0.51	$0.49
HDPE - Mixed Color Pellet	$0.55	$0.62	$0.59
HDPE - Flake	$0.44	$0.49	$0.47
HDPE - Pellet	$0.51	$0.55	$0.53
LDPE - Pellets	$0.41	$0.45	$0.43
LDPE - Flakes	$0.33	$0.37	$0.35
LDPE - Pellets	$0.33	$0.43	$0.38

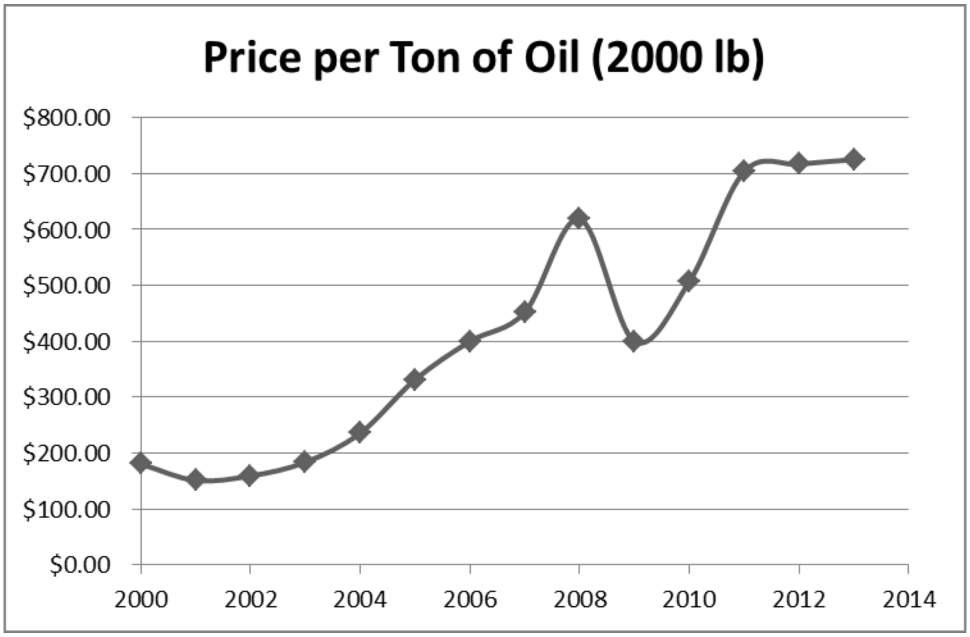
For the purpose of analysis an average value was utilized in the calculations. This was done as the material could be used in any of the above olefin products. The following table identifies the average from the two sources and a cumulative average for all options, which is $.64 per lb. or $1280 per ton.

Table 4 – Average Resin Sale Prices

Average Public Research Value	Average Plastics News	Overall Average Value per Pound
$0.74	$0.54	$0.64

To establish the sales price after the material is converted to oil the market data published by OPEC for the Oil was utilized [21]. The following Figure 8 identifies how these values fluctuate with respect to time. For the purpose of analysis the price of a barrel of oil was converted to a weight measurement of 2000-lb so that the costs be compared to the inputs. For this conversion a factor of 1041.34 Liters per ton was used and a 158.97 Liters per Barrel. For analysis the value of $725.08 per Ton was used for calculations.

Figure 8– Price per Ton of Oil



Results

After the collection and sale prices were established a scenario analysis was completed to determine the optimal point for the combinations of Boat Type, Labor, Fuel as well as whether it would be best to convert to oil or reuse the plastic. Appendix A identifies the formulas that were used in the analysis.

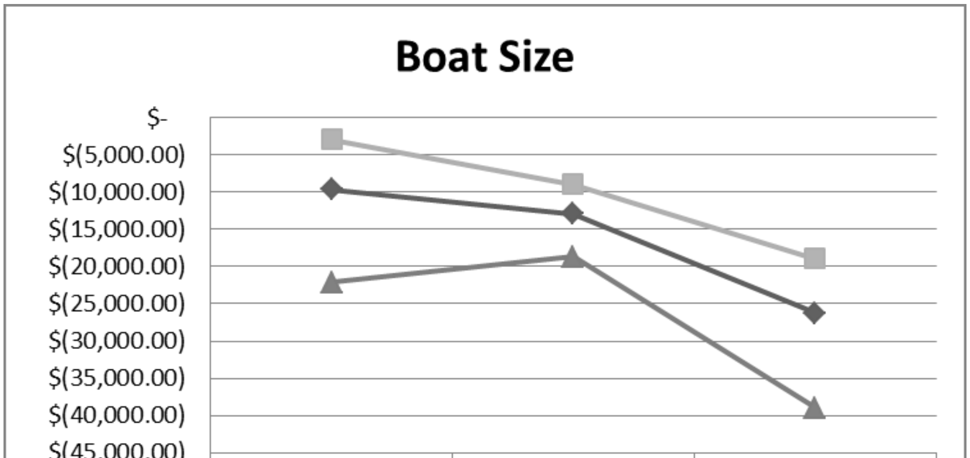
Table 5 identifies the choice scenarios in order of the cost of implementation. As indicated by the table all of the scenarios are money losing ventures.

Table 5 – Cost of Collections Scenarios

Option Number	Boat Type	Labor	Fuel	Convert To Oil	Reuse Plastic	Profit or (Loss)
22	Small	Volunteer	Wind/Sail	No	Yes	$ (2,970.00)
10	Small	Paid	Wind/Sail	No	Yes	$ (3,570.00)
19	Small	Volunteer	Wind/Sail	Yes	No	$ (4,787.49)
7	Small	Paid	Wind/Sail	Yes	No	$ (5,387.49)
16	Small	Volunteer	Diesel	No	Yes	$ (7,458.00)
23	Medium	Volunteer	Wind/Sail	No	Yes	$ (8,970.00)
13	Small	Volunteer	Diesel	Yes	No	$ (9,275.49)
11	Medium	Paid	Wind/Sail	No	Yes	$ (9,420.00)
20	Medium	Volunteer	Wind/Sail	Yes	No	$ (10,787.49)
8	Medium	Paid	Wind/Sail	Yes	No	$ (11,237.49)
17	Medium	Volunteer	Diesel	No	Yes	$ (11,940.00)
14	Medium	Volunteer	Diesel	Yes	No	$ (13,757.49)
5	Medium	Paid	Diesel	No	Yes	$ (18,354.44)
2	Medium	Paid	Diesel	Yes	No	$ (18,722.39)
24	Large	Volunteer	Wind/Sail	No	Yes	$ (18,970.00)
12	Large	Paid	Wind/Sail	No	Yes	$ (19,345.00)
21	Large	Volunteer	Wind/Sail	Yes	No	$ (20,787.49)
9	Large	Paid	Wind/Sail	Yes	No	$ (21,162.49)
4	Small	Paid	Diesel	No	Yes	$ (21,739.68)
1	Small	Paid	Diesel	Yes	No	$ (22,107.62)
18	Large	Volunteer	Diesel	No	Yes	$ (25,240.00)
15	Large	Volunteer	Diesel	Yes	No	$ (27,057.49)
6	Large	Paid	Diesel	No	Yes	$ (38,617.44)
3	Large	Paid	Diesel	Yes	No	$ (38,985.39)

The specific factors can be analyzed to determine the optimal positioning with respect to the alternate options under the factor. Figure 9 illustrates that a small boat is preferred for some of the scenarios but not all, and that the boat size selection is dependent of the other factors that were used in the analysis.

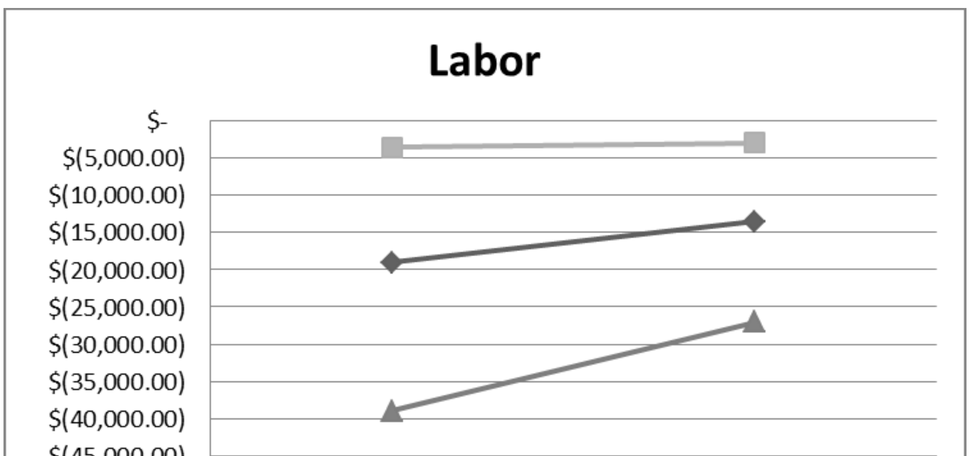
Figure 9 – Cost of Collections with Different Size Boats



	Small	Medium	Large
Average	$(9,661.97)	$(12,898.66)	$(26,270.66)
Max	$(2,970.00)	$(8,970.00)	$(18,970.00)
Min	$(22,107.62)	$(18,722.39)	$(38,985.39)

The factor of Labor type is straight forward as the use of a volunteer for the collection provided a positive benefit to the payment of the crew. However in small boat this factor loses significance as the collection time reduces significantly as compared to the alternate scenario options. Figure 10 illustrates the sensitivity of the Labor Factor.

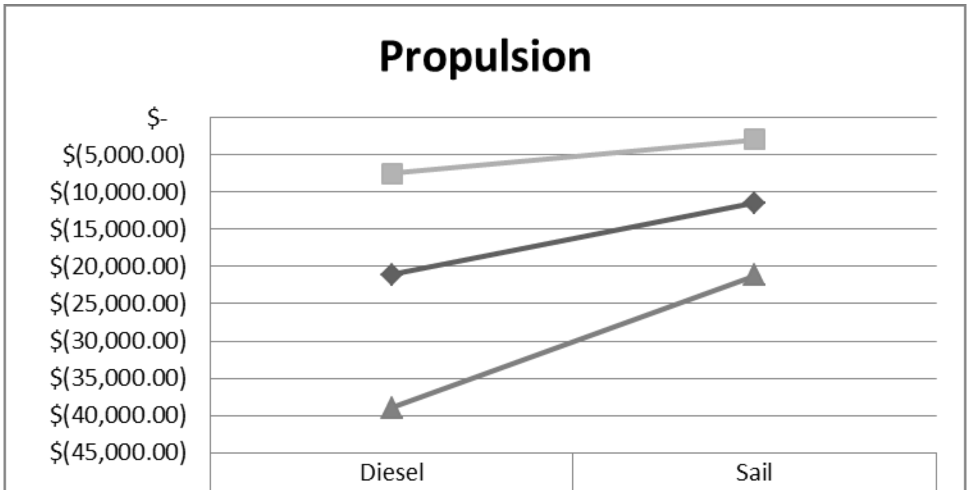
Figure 10 – Cost of Collections with Labor Types



	Paid	Volunteer
Average	$(19,054.12)	$(13,500.08)
Max	$(3,570.00)	$(2,970.00)
Min	$(38,985.39)	$(27,057.49)

The most significant factor in the collection of the plastic depends on the propulsion system of the water craft. Based on this finding shown in Figure 11 it is necessary for the wind based systems to be used when possible to eliminate the costs for collection.

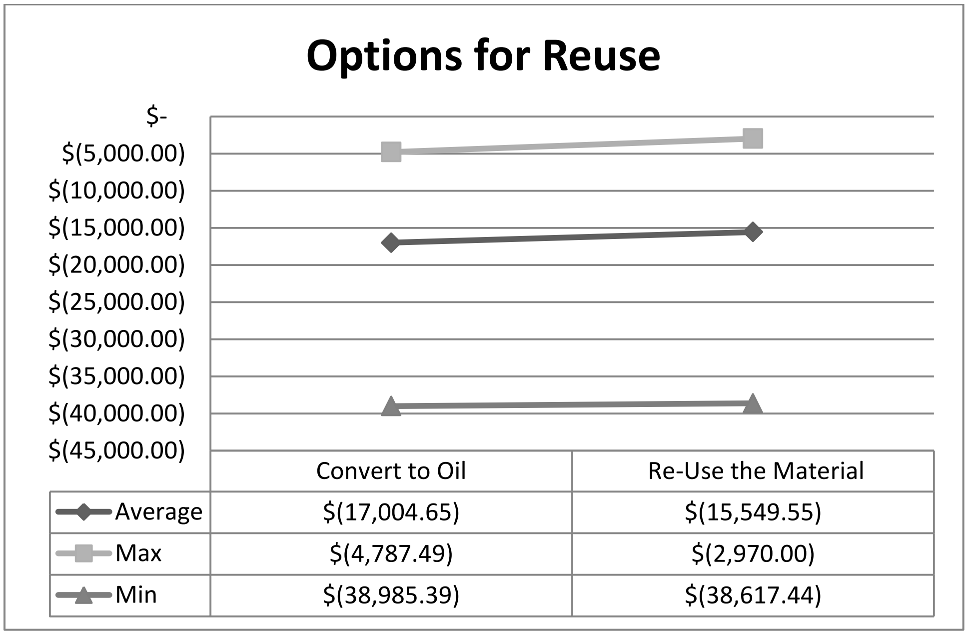
Figure 11 – Cost of Collections with Different Propulsion Types



	Diesel	Sail
Average	$(21,104.62)	$(11,449.58)
Max	$(7,458.00)	$(2,970.00)
Min	$(38,985.39)	$(21,162.49)

In terms of the reuse options the Reuse of the material through compounding is always the best method of reuse however, as the size of the craft increases this value begins to lose significance and have less of an impact on the result. Figure 12 identifies the reuse methods across the different scenarios.

Figure 12 – Reuse Option Comparison



Conclusion:

The conclusion of the economic analysis is that collection of polymers from the Great Pacific Garbage Patch does not currently make a viable financial business case under any of the scenarios considered. There are several factors at play that make this a dynamic analysis. For example, innovations in collection alternatives such as faster, cheaper vessels could make an impact to this analysis. Furthermore, future developments in the technology used to convert synthetic polymers back to oil could have a tremendous impact on the economic analysis. For example, as the price for oil increases and the cost of the technology used for the conversion decreases, the recovery benefit may increase dramatically causing plastics to become a valuable resource. In short, the circumstances warrant continuous attention as shifts in any of the factors could alter the economic results significantly.

In the meantime, given the clear downside of the present situation, steps should be taken to minimize the impact of the garbage patch on ocean health. A simple step is to encourage recycling, reuse, and reduction of plastics. Another approach may involve tighter regulations on the industrial, agricultural, and domestic waste that is released into water bodies. Finally, investing in research and innovation of any factors in the chain of plastic consumption and collection could lead to breakthroughs allowing for cheaper collection or reducing, even eliminating, the garbage that finds its way to the oceans.

Subsidies

Subsidies can be defined as a support, which is given by the governments on any social cause. Public and private organizations can receive subsidies in the form of waste management and recycling grants. Federal, state or local governments generally issue these subsidies. The fees charged on environmentally harmful products or activities often fund subsidies [22].

Appendix A - Financial Equations [12]

Assumptions

Boat	Distance	Fuel Cost	Harvest Rate
	(miles)	($/gal)	(days/ton)
i	***D***	***F***	***H_i***
A	1300	$2.75	1.35
B	1300	$2.75	0.75
C	1300	$2.75	0.52

Data

Boat	Length	Carrying Capacity	Fuel Economy	Cruising Speed	Ship Cost	Crew Cost
	(ft)	(tons)	(gal/hr)	(mph)	($/day)	($/day)
i		***Cap_i***	***E_i***	***R_i***	***B_i***	***Cr_i***
A	<40	1.285	34	28	$2,000	$300
B	40-80	9.75	45	25	$10,000	$450
C	80-120	18.5	190	24	$40,000	$750

Calculations

	Trip Out		Trip Return	Harvest		Total	
Boat	Hours	Trip Cost	Trip Cost	Length	Harvet Cost	Total Cost	Tonnage Cost
	(hrs)	($)	($)	(hrs)	($)	($)	($/ton)
i	***$t_{i,o}$***	***$C_{i,o}$***	***$C_{i,r}$***	***$t_{i,h}$***	***$C_{i,h}$***	***$C_{i,total}$***	***T_i***
A	46	$8,790	$8,790	42	$7,883	$25,464	**$19,816**
B	52	$29,077	$29,077	176	$98,134	$156,287	**$16,029**
C	54	$120,273	$120,273	231	$512,650	$753,195	**$40,713**

Following the variables shown in the above tables, the formulas for cost of collection are as follows:

$$C_{i,o} + C_{i,h} + C_{i,r} = C_{i,total}$$ [Total cost equal to cost of travel out, return, and harvest]

$$C_{i,o} = t_{i,t}[(F * E_i) + {}^{B_i}/_{24} + {}^{Cr_i}/_{24}]$$ [Cost of travel out includes 3 terms: cost of fuel, boat, crew]

where $t_{i,t} = {}^{D}/_{R_i}$ [Time of travel equal to distance divided by cruising speed]

$C_{i,o} \cong C_{i,r}$ [Assuming the cost of travel out is generally equal to cost of travel return]

$C_{i,h} = t_{i,h}[(F * E_i) + {}^{B_i}/_{24} + {}^{Cr_i}/_{24}]$ [Cost of travel includes same 3 terms: fuel, boat, crew]

where $t_{i,h} = H_i * Cap_i * 24$ [Time of harvest equals product of harvest rate and boat capacity]

$T_i = {}^{C_{i,total}}/_{Cap_i}$ [Cost per ton equal to total cost of trip divided by ship payload]

Cost tables for each scenario is shown below.

Original Scenario

Data							Assumptions			Calculations						
										Trip Out		Trip Return	Harvest		Total	
Boat	Length	Carrying Capacity	Fuel Economy	Cruising Speed	Ship Cost	Crew Cost	Distance	Fuel Cost	Harvest Rate	Hours	Trip Cost	Trip Cost	Length	Harvet Cost	Total Cost	Tonnage Cost
	(ft)	(tons)	(gal/hr)	(mph)	($/day)	($/day)	(miles)	($/gal)	(days/ton)	(hrs)	($)	($)	(hrs)	($)	($)	($/ton)
i		Cap_i	E_i	R_i	B_i	Cr_i	D	F	H_i	$t_{i,o}$	$C_{i,o}$	$C_{i,r}$	$t_{i,h}$	$C_{i,h}$	$C_{i,total}$	T_i
A	<40	1.285	34	28	$2,000	$300	1300	$2.75	1.35	46	$8,790	$8,790	42	$7,883	$25,464	**$19,816**
B	40-80	9.75	45	25	$10,000	$450	1300	$2.75	0.75	52	$29,077	$29,077	176	$98,134	$156,287	**$16,029**
C	80-120	18.5	190	24	$40,000	$750	1300	$2.75	0.52	54	$120,273	$120,273	231	$512,650	$753,195	**$40,713**

No-Labor Scenario

										Trip Out		Trip Return	Harvest		Total	
Boat	Length	Carrying Capacity	Fuel Economy	Cruising Speed	Ship Cost	Crew Cost	Distance	Fuel Cost	Harvest Rate	Hours	Trip Cost	Trip Cost	Length	Harvet Cost	Total Cost	Tonnage Cost
	(ft)	(tons)	(gal/hr)	(mph)	($/day)	($/day)	(miles)	($/gal)	(days/ton)	(hrs)	($)	($)	(hrs)	($)	($)	($/ton)
i		Cap_i	E_i	R_i	B_i	Cr_i	D	F	H_i	$t_{i,o}$	$C_{i,o}$	$C_{i,r}$	$t_{i,h}$	$C_{i,h}$	$C_{i,total}$	T_i
A	<40	1.285	34	28	$2,000	$0	1300	$2.75	1.35	46	$8,210	$8,210	42	$7,362	$23,783	**$18,508**
B	40-80	9.75	45	25	$10,000	$0	1300	$2.75	0.75	52	$28,102	$28,102	176	$94,843	$151,046	**$15,492**
C	80-120	18.5	190	24	$40,000	$0	1300	$2.75	0.52	54	$118,580	$118,580	231	$505,435	$742,595	**$40,140**

No-Fuel Scenario

										Trip Out		Trip Return	Harvest		Total	
Boat	Length	Carrying Capacity	Fuel Economy	Cruising Speed	Ship Cost	Crew Cost	Distance	Fuel Cost	Harvest Rate	Hours	Trip Cost	Trip Cost	Length	Harvet Cost	Total Cost	Tonnage Cost
	(ft)	(tons)	(gal/hr)	(mph)	($/day)	($/day)	(miles)	($/gal)	(days/ton)	(hrs)	($)	($)	(hrs)	($)	($)	($/ton)
i		Cap_i	E_i	R_i	B_i	Cr_i	D	F	H_i	$t_{i,o}$	$C_{i,o}$	$C_{i,r}$	$t_{i,h}$	$C_{i,h}$	$C_{i,total}$	T_i
A	<40	1.285	34	28	$2,000	$300	1300	$0.00	1.35	46	$4,449	$4,449	42	$3,990	$12,889	**$10,030**
B	40-80	9.75	45	25	$10,000	$450	1300	$0.00	0.75	52	$22,642	$22,642	176	$76,416	$121,699	**$12,482**
C	80-120	18.5	190	24	$40,000	$750	1300	$0.00	0.52	54	$91,970	$91,970	231	$392,015	$575,956	**$31,133**

No-Fuel & No-Labor

										Trip Out		Trip Return	Harvest		Total	
Boat	Length	Carrying Capacity	Fuel Economy	Cruising Speed	Ship Cost	Crew Cost	Distance	Fuel Cost	Harvest Rate	Hours	Trip Cost	Trip Cost	Length	Harvet Cost	Total Cost	Tonnage Cost
	(ft)	(tons)	(gal/hr)	(mph)	($/day)	($/day)	(miles)	($/gal)	(days/ton)	(hrs)	($)	($)	(hrs)	($)	($)	($/ton)
i		Cap_i	E_i	R_i	B_i	Cr_i	D	F	H_i	$t_{i,o}$	$C_{i,o}$	$C_{i,r}$	$t_{i,h}$	$C_{i,h}$	$C_{i,total}$	T_i
A	<40	1.285	34	28	$2,000	$0	1300	$0.00	1.35	46	$3,869	$3,869	42	$3,470	$11,208	**$8,722**
B	40-80	9.75	45	25	$10,000	$0	1300	$0.00	0.75	52	$21,667	$21,667	176	$73,125	$116,458	**$11,944**
C	80-120	18.5	190	24	$40,000	$0	1300	$0.00	0.52	54	$90,278	$90,278	231	$384,800	$565,356	**$30,560**

Table 6 – Costs to Convert to Oil Example

Boat	Total Boat Cost per Ton	Electricity Cost	Electricity Cost	Sales Price	Conversion	Sale Price	Profit/Loss
	($/Ton)	($/KWh)	($/Ton)	($/Liter)	(Liter/Ton)	($/Ton)	($/Ton)
i	***A***	***B***	***C***	***D***	***E***	***F***	***G***
A	$ (22,770)	$ (0.07)	$ (63)	$ 0.70	1041.34	$ 725	$ (22,108)
B	$ (19,384)	$ (0.07)	$ (63)	$ 0.70	1041.34	$ 725	$ (18,722)
C	$ (39,647)	$ (0.07)	$ (63)	$ 0.70	1041.34	$ 725	$ (38,985)

Formulas – Costs to Convert to Oil Example

$$C\left(\frac{\$}{Ton}\right) = B\left(\frac{\$}{KWh}\right) * 909\,\frac{kg}{ton} * 1\left(\frac{KWh}{kg}\right)$$

$$F\left(\frac{\$}{Ton}\right) = D\left(\frac{\$}{Liter}\right) * E\left(\frac{Liter}{Ton}\right)$$

$$G\left(\frac{\$}{Ton}\right) = A\left(\frac{\$}{Ton}\right) + C\left(\frac{\$}{Ton}\right) + F\left(\frac{\$}{Ton}\right)$$

Table 7 – Costs to Re-compound Example

Boat	Total Boat Cost per Ton ($/Ton)	Cost to Compound ($/Pound)	Cost to Compound Conversion ($/Ton)	Sale Price ($/Pound)	Sale Price Per Ton ($/Ton)	Profit/Loss ($/Ton)
i	*H*	*I*	*J*	*K*	*L*	*M*
A	$ (22,770)	$ (0.13)	$ (250)	$ 0.64	$ 1,280	$ (21,740)
B	$ (19,384)	$ (0.13)	$ (250)	$ 0.64	$ 1,280	$ (18,354)
C	$ (39,647)	$ (0.13)	$ (250)	$ 0.64	$ 1,280	$ (38,617)

Formulas – Costs Re-compound Example

$$J\left(\frac{\$}{ton}\right) = 2000\left(\frac{lb}{ton}\right) * I\left(\frac{\$}{lb}\right)$$

$$L\left(\frac{\$}{Ton}\right) = 2000\left(\frac{lb}{ton}\right) * K\left(\frac{\$}{lb}\right)$$

$$M\left(\frac{\$}{Ton}\right) = H\left(\frac{\$}{ton}\right) + J\left(\frac{\$}{ton}\right) + M\left(\frac{\$}{Ton}\right)$$

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