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Treatment of Plastic Wastes using Plasma Gasification Technology

An Undergraduate Thesis Proposal

By

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Abstract:

Plasma gasification (PG) complements traditional recycling when applied to contaminated or mixed plastics. Without PG these plastics cost recyclers more to process than they are worth on the market, and sometimes they are landfilled or incinerated instead of being recycled. Plasma gasification can take plastic not suitable for traditional recycling and break it down into high-quality syngas for use in electricity generation, chemical manufacturing, or hydrogen production. The technology can be implemented without changing the behavior of consumers, which is a major advantage over attempting to decrease contamination or reduce use of low-value plastic. Due to high capital requirements and maintenance costs, a PG facility processing 300 tons/day of waste plastic was found to be profitable without subsidies with a payback period of about 11-12 years. However, the cash flow analysis showed at 15 years the Net Present Value (NPV) was -$9,159,467.73 with an Internal Return Rate (IRR) of 3.8%. The large investment required to commercialize the technology at the scale required may not add enough value over the course of 15 years to justify the risk.

Intro:

At a time when humanity is experiencing a revolution in green energy tech, our waste management systems and techniques are due for an upgrade in sustainability. Recycling is only effective at recovering high value products such as metals or some types of plastics with low contamination [13], leaving other materials to be landfilled or incinerated. Landfills have been known to leech various chemical and organic contaminants into surrounding groundwater [11], and incineration requires air pollution control (APC) to avoid dangerous emissions which produces concentrated residues to be landfilled [20]. Plasma gasification of plastic waste rejected by the recycling industry can recover energy from plastic at the end of its useful life without the harmful reactions of combustion.

Current recycling behaviors and habits are not effective at producing high value products. Many recyclers have transitioned to single-sort recycling, while this is convenient for consumers it results in a heterogeneous mix of materials with relatively high contamination rates [23]. These materials are more expensive to clean and process which cuts into already thin recycler profit margins [23]. With current methods it is possible to economically separate and recycle cardboard, paper, metals, PET plastic (#1), and HDPE plastic (#2). However mixed plastics #3-7 are low value and recyclers may struggle to find buyers willing to pay more for recycled materials than for virgin materials [2]. As of September 21st 2018, mixed #3-7 was selling for under \$20/ton compared to \$820/ton for HDPE and \$330/ton for PET [Secondary Materials Pricing]. **Table 01** details the prices of post-consumer plastics. At prices this low, recyclers are seldom able to profit off the sale of mixed plastics, and some are forced to sell at a loss or landfill low value products [9].

Table 01

Plastic Type	Number Designation	Price of post-consumer material in December 2017 ($US/ton)	Price of post-consumer material in September 2018 ($US/ton)	Price of virgin material in October 2018 ($US/ton)
Polyethylene Terephthalate (PET)	#1	271.80	330.00	1600.00[a]
High-Density Polyethylene (HDPE)	#2	602.60	820.00	1500.00[b]
Mixed Plastics	#3-7	12.60	20.00	N/A

Table 01 shows the price of post-consumer materials in December 2017 (pre-Chinese National Sword policy), post-consumer material prices in September 2018 (both from Secondary Materials Pricing), and virgin plastic prices ([a] – Sound Resource Management Group, Inc. [b] – Plasticker Market Report Plastics). Mixed plastics are only created through recycling practices, therefore virgin material prices are not applicable.

With new policies coming into effect in China regarding the quality and contamination of imported recyclables, the amount of plastic imported by China fell from 1.23 million metric tons in January and February of 2017 to just 10 thousand metric tons in the same period of 2018 [21]. This has left a glut of material sorted by recyclers without a buyer. As bales of plastic pile up recyclers have to decide between stockpiling plastic and sending it to a landfill [9], and because China accepted about half of the world's recyclables in 2017, it is piling up fast. To make matters worse, global plastic use has nearly doubled in the past 10 years and shows no signs of stopping as seen in **Figure 01** [25]. Better sorting and cleaning could provide an acceptable product to recyclers, but would require either a widespread change in recycling behavior or more processing for a low value product. This paper will propose an alternative solution to this problem by using PG to process low value and/or contaminated plastics. The plasma arc reaches temperatures high enough to gasify both the plastic and any contaminants [8]. Although PG can be used to treat a wide variety of wastes ranging from MSW to biomedical waste [8], mixed plastic is a great feedstock because it is made up of mostly Carbon and

Hydrogen [15]. The resulting syngas is clean relative to more variable gasification feedstocks, which lessens processing requirements to remove Nitrogen, Sulphur, Arsenic, and tars [3].

Figure 01

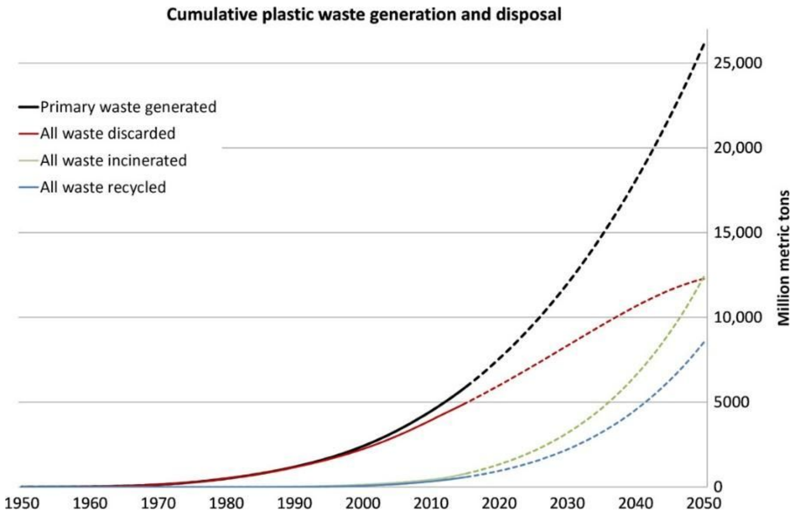

Figure 01 shows historical global plastic use from 1950 to 2015 with a solid line, and projected usage from 2015 to 2050 based on historical trends [10].

Plasma gasification is a potentially transformative technology capable of extracting stored energy from undesired plastic waste [18]. Plasma gasification can turn a wide variety of feedstocks such as municipal solid waste (MSW) or mixed plastics into an array of usable products ranging from construction materials [22] to fuels for use in electricity production and/or transportation [19, 17]. Plasma gasification works by superheating the waste with a plasma arc to break it down into an inert solids, as well as a mix of hydrogen, carbon monoxide, and other trace gases known as syngas [18]. The inert solids left over after gasification have favorable leaching characteristics and can be used in the construction industry to displace other materials [3]. At this point the syngas can then be burned to generate electricity or further processed into different chemical products [8]. Markets for syngas produced through PG vary but range from combustion for electricity and heat, processing to synthetic liquid fuels, or purification into a hydrogen energy carrier [7]. Multiple markets for high-quality syngas is a good thing because it ensures syngas' value through ups and downs in a single market.

Research Questions:

1) Can Plasma Gasification (PG) technology complement conventional recycling methods to reduce waste and increase profitability?

2) Could an estimation of profitability be created for a PG facility running on plastic waste in California be created?

Literature Review:

Plasma gasification is a versatile technology and can be used to process many different feedstocks without requiring a homogeneous mixture. The technology can be used to process almost any feedstock regardless of biohazards or moisture content by breaking it down into simple compounds such as gaseous carbon monoxide and hydrogen as well as an inert solid called slag [22]. Plasma gasification processes waste through the use of plasma torches, an example of Westinghouse Plasma Corporation's (WPC) torch is shown below in **Figure 02**. A plasma torch applies a high voltage to a working gas, which heats it to temperatures up to 6000C. The temperature of the plasma torch is dependent on the voltage applied, and it can be adjusted to accommodate feedstocks with varying energy contents [25]. An important difference between PG and incineration is that PG involves only partial oxidation, while incineration involves more complete oxidation through combustion. Limiting the reaction to partial oxidation combined with high temperatures prevents the formation of many tars, as well as dioxins and furans which are extremely hazardous to human health even in small amounts [16].

Figure 02

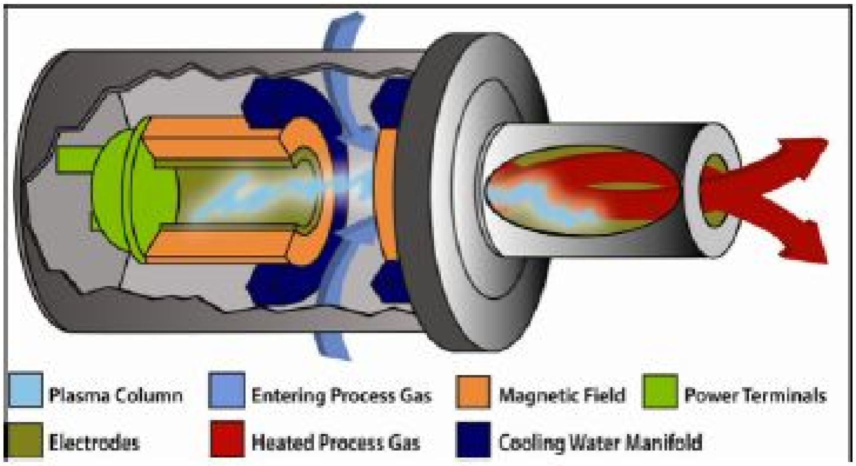

Figure 01 shows a cutaway diagram of a Westinghouse Plasma Corporation plasma jet. The heated gases exit the torch on the right side of the diagram and enter the gasification chamber where the gas is allowed to interact with the wastes to produce syngas and other products [22].

The plasma gasifier is made up of a closed chamber with up to six plasma jets arranged to heat the feedstock [22]. While many configurations exist, this paper will focus on the gasifier designed by Alter NRG because it has been applied multiple times worldwide and has been proven as effective. A visualization of their design is shown in **Figure 03.** In this design the feedstock is added to the gasifier from above, where it works its way downward towards the plasma jets as the material underneath it is gasified. The syngas rises above the ungasified feedstock to be collected at the top of the gasifier where it can be collected for further processing or use.

Figure 03

Figure 03 shows Alter NRG's plasma gasifier design using six Westinghouse Plasma Corporation plasma jets. Waste is added through the central feed port and the resulting syngas is collected at the top of the gasifier. Plasma torches are arranged in a circular pattern to distribute the heat energy evenly. Plasma torch electrodes must be replaced periodically as their electrodes oxidize. This design allows the gasifier to continue operation even if one or two of the plasma jets have been removed for servicing [24].

Organic compounds made up of carbon in combination with hydrogen, oxygen, and/or nitrogen are gasified and broken into simple components by the high heat of a plasma torch and collected at the top of the gasifier as syngas [22]. This raw syngas is made up of mostly carbon monoxide and hydrogen, but to obtain a higher value product the low heating value (LHV) of the gas must be increased, usually by encouraging H_2 formation. This can be done through the water-gas shift reaction, in which steam is pumped into the gasifier where **Reaction 1** takes place. The resulting syngas is made up of primarily carbon dioxide and hydrogen gas [25]. This refined syngas has a heating value modestly lower than natural gas, but can be used as an input in a wide variety of industrial applications.

Reaction 1 $CO + H_2O = CO_2 + H_2$

When using heterogeneous feedstocks such as the municipal solid waste (MSW), the inorganic compounds are not easily broken down and melt into a mixture which is drained from the bottom of the gasifier, this mixture is called slag. The slag locks in heavy metals and other harmful compounds in an inert solid [25]. Once cooled the slag can be used to make bricks and other building materials or used as an aggregate for cement production. Unlike Air Pollution Control Residues (APCR's) the slag resists leaching of heavy metals and other contaminants. This makes it a suitable construction material to use in urban areas where contact with both water and humans is frequent [22]. This use allows slag to displace other materials that would otherwise have to be collected and shipped to construction sites, instead reusing material already claimed by civilization.

When applied to plastic waste, PG produces syngas with a higher hydrogen content than syngas produced with a MSW feedstock. Syngas produced from a plastic feedstock is composed of 62% H_2, 34% CO, with the remaining 4% trace gases composed of CO_2 and CH_4 [15]. Alternatively syngas produced with a feedstock of MSW is composed of 41% CO, 34% H_2, 14% CO_2, 6% H_2O, and 4% CH_4 with some trace hydrochloric acid and hydrogen sulfide (<.2% each) [22]. Hydrogen gas has a very high LHV of 120 MJ/kg, so syngas with more hydrogen as a percentage will have a higher LHV. Additionally the presence of water vapor in a fuel will lower its' LHV. As a result, syngas produced from MSW would be expected to have significantly lower energy content than syngas produced with waste plastics, as well as containing more contaminants. This makes syngas produced with waste plastics objectively higher in quality.

High-quality syngas has several potential applications in different sectors. It can be used as a feedstock to synthesize liquid fuels using the Fischer-Tropsh process, burned to produce electricity, or potentially further processed to isolate H_2 for use in chemical manufacturing or as a transportation fuel. Because syngas has so many uses in different industries, it should be able to maintain a relatively stable value through fluctuations in the price of its substitutes.

Research Questions:

1) Can PG technology complement conventional recycling methods to increase the efficiency of resource allocation and reduce the volume of plastic landfilled?

2) Could an estimation of profitability PG facility running on plastic waste in California be created?

Methods:

To predict the viability of PG technologies for use in energy recovery from waste plastics, this paper will include an economic analysis of a hypothetical 300 tons/day PG plant using a waste plastic feedstock, located on the west coast in California. This location was chosen for three main reasons, its high population density ensures a steady supply of waste plastic, favorable attitudes towards environmental regulation provide potential for subsidies and tax incentives, proximity to China gives access to materials rejected by new Chinese standards, and hydrogen vehicles could potentially provide demand for high-value hydrogen fuel created with syngas. In addition to the economic analysis of the plant, a cash flow analysis will be included to determine payback period, net present value, and return on investment.

The economic analysis will be a modification of the analysis completed by Caroline Ducharme in 2010, where the feedstock for the PG plant is mixed/waste plastic instead of MSW [6]. Ducharme's analysis includes information about capital, operation, and labor costs for a PG plant I was unable to find elsewhere. Therefore this information has been included in the analysis, adjusted to compensate for a smaller facility due to a limited plastic feedstock. Before this information was used, it was adjusted for inflation estimated to be ~16% between 2010 to 2018 [Bureau of Labor]. Plant costs are and broken down into capital costs, labor costs, maintenance costs. Plant income is primarily through the sale of electricity to the grid, but income from the sale of purified and compressed hydrogen is also listed in parenthesis. This will not be used in the final economic analysis due to additional equipment and personnel needs, but will still be listed because its high value may justify the increased capital and maintenance costs. Sales of recovered metal and slag are assumed to be negligible. Because the plastic feedstock is almost entirely made of organic material, effectively all of the material will be gasified rather than vitrified.

Economic Analysis:

The economics of a new technology plays an important role in determining whether it is ultimately adopted or left behind. Barring the introduction of government policies subsidizing the technology or mandating its use, if the technology cannot make money it is unlikely to be adopted over more profitable alternatives. As stated above, this analysis borrows heavily from Caroline Ducharme's 2010 analysis [6].

Expenses: Ducharme's study it was assumed the plant would operate 330 days per year, leaving 35 days for shutdowns and maintenance/repairs. In 2016, the California Department of Resources Recycling and Recovery estimated 500,000 tons of low grade plastic were exported from California. It is unreasonable to assume a single facility would be responsible for the entire state's plastic waste, therefore 300 tons/day is the chosen capacity and gives an annual capacity for a 300 ton/day plant of 330 days/year * 300 tons/day = 99,000 tons/year. This corresponds to just under 20% of California's annual exports of low-grade material, which seems like an attainable goal to prove the viability of the technology. Assuming \$650/annual ton of capacity [6], capital costs can calculated as \$650/annual ton * 99,000 tons/year = \$64,350,000. However this does not include the cost of the plasma arc estimated to be \$27,400,000 [5], bringing the capital costs to \$91,750,000. Using an inflation rate of 16% from 2010 to 2018 [Bureau of Labor Statistics, consumer price index], this gives us total capital costs of \$106,430,000. Assuming capital costs need to be paid back at 10% per year, this gives us an annual cost of \$10,643,000 to be split over 99,000 tons/year. This gives capital costs of **\$108/ton.**

Ducharme's study says 50 people can handle a 750 ton/day facility with labor costs of $2,500,000/year. Therefore it is assumed roughly 25 people should be able to handle a 300 ton/day facility with about $1,250,000 in labor costs per year. Using the same inflation rate as above, this gives annual labor costs of $1,450,000. Labor costs per ton of feedstock can be calculated by $1,450,000 / 99,000 tons/year = **$15/ton.** This assumption is probably an overestimation of the labor needs of the smaller plant, so actual costs in practice may be marginally lower.

Maintenance costs for a PG facility will be difficult to estimate because companies developing the technology are hesitant to release information. This is likely because the maintenance costs are heavily dependent on the lifetime of the plasma electrode. For a 750 ton/day plant Ducharme estimated $10,669,000 in annual maintenance costs. For a plant less than half that size, the maintenance costs will likely still be around half of the larger plant. The assumed cost for this smaller plant will be $5,500,000/year. Using the above inflation rate of 16% over eight years, the operating costs should be about $6,380,000. The cost per ton is calculated as $6,380,000/year / 99,000 tons/year = **$64/ton.**

For this economic analysis, the plant will pay market value for mixed plastics #3-7 at **$20/ton**. In practice this number will almost certainly be less than this. Since the technology can also be applied to contaminated plastics rejected by recyclers, this material can likely be obtained for a much lower cost. Recyclers may be willing to pay for to send material to a PG facility if the alternative is paying high landfill fees for disposal.

Income: The plant's main source of income will be through the sale of electricity to the grid. Punochar calculates 1 kg of plastic contains about 43.5 MJ of energy, of which 13.05 MJ is recoverable as electrical energy [18]. Converting to kWh/kg and subtracting the energy required for the plasma arc leaves 2.4 kWh/kg of plastic. 2.4 kWh/kg * 1000 kg/tonne / 1.1 tons/tonne = 2200 kWh/ton. In southern California, wholesale electricity costs range from $0.37/kWh to $0.02/kWh depending on the source and time of year. For this study a conservative price of \$0.13/kWh is assumed: 2200 kWh/ton * \$0.13/kWh = **\$286/ton.**

Instead of burning syngas to produce electricity, the hydrogen can be isolated, purified, and compressed to be sold on the market. With retail prices for hydrogen of almost \$14/kg, this could be a lucrative product especially if the world begins to transition toward a hydrogen economy. Annual hydrogen production can be calculated through syngas yields, hydrogen content, and some of the physical properties of hydrogen. 99,000 tons/year * 907 kg/ton = 89,793,000 kg/year. According to a 2013 paper by Lopez et al. plasma gasification of a waste plastic feedstock produced 3.5 m3 of syngas for every kg of feedstock, with 62% of the gas being hydrogen. 89,793,000 kg/year * 3.5 m^3 syngas/ kg @1200C * .62 m^3 H_2/m^3 syngas = 194,850,810 m^3 H_2/year @1200C. At 1200C, 1m^3 of H_2 contains 8.27 moles of H_2. After cooling, one mole of H_2 gas contains .00202 kg of H_2. 194,850,810 m^3 H_2 @1200C * 8.27 moles H_2/m^3 H2 * .00202 kg H_2/mole H_2 = 3,255,060 kg H_2. While retail price of H_2 is nearly \$14/kg, it must be compressed and transported before it can be sold. Including compression and transportation, \$6/kg represents a realistic net income from the sale of hydrogen. 3,255,000 kg H_2 * \$6/kg H_2 = \$19,530,360/year. \$19,530,360/year / 99,000 tons/year = **\$197/ton**

With a waste plastic feedstock for the plant, the sale of metals and slag will be negligible **\$0/ton.**

Table 01

PG expenses	**\$US/ton**	**PG revenues (Electricity)**	**\$US/ton**	**PG revenues (Hydrogen)**	**\$US/ton**
Capital charges [6]	108	Electricity to grid [18]	286	Hydrogen Production [15]	197

Labor costs [6]	15	Metal and slag	0	Metal and slag	0
Operation and maintenance [6]	64				
Feedstock price [a]	20				
Total Expenses	207	**Total Revenues (Electricity)**	286	**Total Revenues (Hydrogen)**	197

Table 01 shows estimated expenses and income for a 300 tpd PG plant shown in $US/ton of feedstock. Hydrogen and electricity production are shown separately because syngas is consumed to make each. Hydrogen ends up being the less valuable product, and may also include higher costs to produce it. [a] – Secondary Materials Pricing

Based off these numbers, the plant appears to be economically viable. Even assuming the plant must pay $20/ton for the waste plastic feedstock, the plant produces a profit of over $100/ton of feedstock processed. In practice, the plant would likely be able to obtain contaminated feedstock not suitable for recycling at a lower price. Theoretically the plant could process any material rejected by the recycling facility, which the recycler may actually be willing to pay some amount for disposal.

Cash Flow Analysis:

The cash flow analysis assumes an inflation rate of 2.5% per year. This rate is applied to both the price for electricity and operating costs. The payback period of this plant was calculated to be between eleven and twelve years, and at 15 years the Net Present Value (NPV) was -$9,159,467.73 and a return rate of 3.8%. The full analysis with annual income and expense estimations is included in the appendix.

Discussion:

Plasma gasification has the potential to increase the efficiency of our recycling systems. It can do this by supplementing existing recycling, allowing resources currently not recyclable using conventional methods to be utilized again in the economy. One of the biggest advantages to this technology is these improvements can be made without changing the behavior of consumers on an individual level. While the optimal solution would be to reduce use of conventionally non-recyclable plastics and decrease contamination, these seem unlikely to work especially in communities where recycling is not mandated. If recycling seems too complicated or inconvenient to consumers, some will elect to not participate. Plasma gasification allows recyclers to mitigate some of the downsides brought on by single-stream recycling while still taking advantage of increased participation encouraged from consumers.

The discovery of the Great Pacific Garbage Patch in 1997 brought plastic buildup in the oceans into focus for the world [19]. 21 years later, there are a few groups working on cleaning plastic out of the water but not as many working on what to do with plastic after it has been recovered. Much of the waste has spent years if not decades in the ocean, where UV rays from the sun and saltwater can cause the plastic to break into microscopic bits. This makes the plastic both harder to filter from seawater, and harder to recycle after recovery. This source of waste plastic may be best processed through PG due to the increased difficulty of sorting very small bits of plastic for traditional recycling.

Plasma gasification may prove to be a valuable technology because it produces energy and materials out of a low value input. With recyclers struggling to get rid of both mixed and contaminated plastics and usage trending higher than ever, there should be no shortage in supply of waste plastics in the coming years. In addition to being used on plastics, PG is also a suitable method to destroy biomedical waste [3]. Currently this waste is incinerated to destroy any pathogenic or otherwise harmful components in the waste, but PG can also do this effectively. This could provide another source of income for a PG plant, as hospitals currently pay as much as $400-1000/ton to dispose of such waste [Sharps Compliance, Inc.].

In early November 2018, Bloomberg News reported on a plastic-to-fuel plant coming to Indiana. The company organizing the project RES Polyflow plans to begin construction early in 2019 on a plant processing 100,000 tons/year of plastic feedstock to produce diesel and other fuels. So far the project has secured $10 million in funding from Brightmark, with another $37 million being requested from the same group. RES Polyflow is hoping to finance the rest of their costs through public bonds [1], although the amount of public funds was not reported. This plant is similar in size to the one in the economic analysis above (100k tons/year vs 99k tons/year), so the project is still likely in need of tens of millions in additional funding to near the $92 million in overall costs estimated for my slightly smaller plant.

To encourage the construction of a plant using PG technology for chemical recycling, policy changes mandating recycling of all plastics may be needed. Without such a policy the capital investment required to build such a plant might prove too risky for many investors. However with a policy banning plastic from landfills in place, recyclers would be forced to send materials not conventionally recycled to alternative recycling facilities such as PG plants. This can allow recyclers more flexibility to send materials to PG when the market for recycled materials is poor or when the material is too contaminated to be recycled effectively. Alternatively policies can be put in place to reward bond money to advanced waste management practices. This might make the high construction costs easier to swallow for prospective investors.

Plasma gasification could potentially decrease the price consumers must pay to recycle. Currently recyclers are forced to spend money to separate low-value plastics from #1 and #2 plastics before they can be sold. But these plastics aren’t worth very much on the market, so recyclers get most of their profit off selling high-value plastics. Since China stopped accepting most low-grade plastic for recycling, the market for it has declined sharply [21]. This results in recyclers being forced to sell for less than the cost of separating the plastic, or opting to landfill or incinerate it [9]. This cost for recyclers ends up being passed on to the consumer in the form of higher recycling fees [12]. Plasma gasification can help alleviate this problem by supporting a market for low-grade and contaminated plastic.

Syngas has several applications and can be used to do more than just generate electricity. A potential use for syngas in the coming years is as a feedstock for H_2 production for use in transportation. After the water-gas shift reaction, the syngas is made up of mostly H_2 and CO_2. From here the syngas can be pumped through a CaO filter, which captures CO_2 through **Reaction 02** [14]. The resulting gas is nearly pure H_2, which would then be cooled and compressed before being shipped to hydrogen refueling stations for use in hydrogen fuel cells. Hydrogen fuel cell vehicles combine many of the convenient features of gas engines such as fast refueling and high fuel energy density with the environmental advantages of zero-tailpipe-emissions [17], and may be the key to replacing fossil fuel transportation in time to avoid catastrophic climate change. The filters are replaced, and can be heated in another location to release their stored CO_2 for use in greenhouses, industrial manufacturing, or sequestration. After CO_2 is removed from the filters, they can be reinstalled at the PG plant to capture CO_2 again. The increased global attention to climate change means avoiding the release of greenhouse gases will be a crucial to the implementation of this technology.

Reaction 02 $CaO + CO_2 \leftarrow\rightarrow CaCO_3$

Plasma gasification is an incredibly versatile technology which can be applied to much more than just plastic waste. Although plastic makes a great feedstock due to the high-quality syngas it produces when gasified, PG can also be applied to general MSW. In areas where landfill costs are high, PG of MSW may be a more economical option than the status quo. Because of the compact nature of the gasifiers, the plant could be expanded to handle MSW for energy recovery and materials production.

Conclusion:

A PG facility running on waste plastic produces syngas with superior energy content and tar content when compared to other potential feedstocks. When applied to mixed or contaminated plastics the technology is able to create valuable products out of a low-value input. Reduced sorting requirements and higher contamination tolerance may prove an important solution to problems created by the single-stream collection methods common in the United States presently. Consumers will not have to change their recycling habits, but recyclers may see significant reductions in cost and/or increased income from sale of mixed plastics. The energy content in syngas created through PG of plastics is favorable for electricity production and allows the syngas to be utilized without the logistics of moving it off-site for use. However there is potential to use the high-quality syngas for to crease other products such as synthetic fuels While a PG plant running on a waste plastic feedstock is economically viable, some policy changes would likely be needed before a facility is built and operating. A 3.8% return rate is simply too low to excite private investors, although there may be some room for public entities such as cities to share some of the costs. Without mandates banning plastic from landfills or subsidies to offset costs, PG will likely be seen as too risky to justify the large investment of capital needed to construct and operate the plant.

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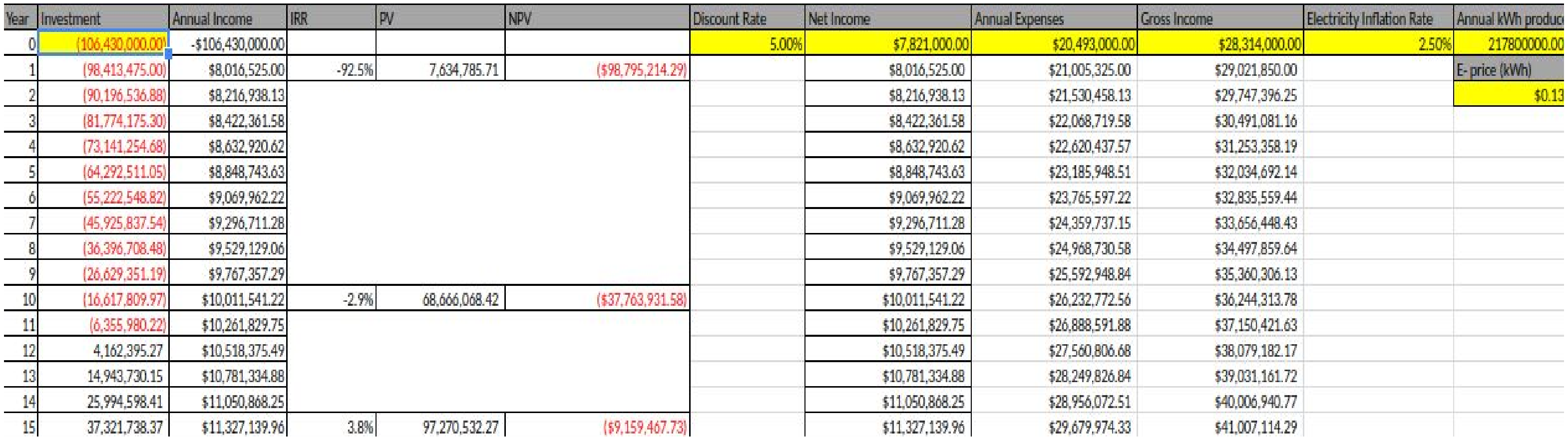
Appendix



Year	Investment	Annual Income	IRR	PV	NPV	Discount Rate	Net Income	Annual Expenses	Gross Income	Electricity Inflation Rate	Annual kWh produc
0	(106,430,000.00)	-$106,430,000.00				5.00%	$7,821,000.00	$20,493,000.00	$28,314,000.00	2.50%	217800000.00
1	(98,413,475.00)	$8,016,525.00	-92.5%	7,634,785.71	($98,795,214.29)		$8,016,525.00	$21,005,325.00	$29,021,850.00		E- price (kWh)
2	(90,196,536.88)	$8,216,938.13					$8,216,938.13	$21,530,458.13	$29,747,396.25		$0.13
3	(81,774,175.30)	$8,422,361.58					$8,422,361.58	$22,068,719.58	$30,491,081.16		
4	(73,141,254.68)	$8,632,920.62					$8,632,920.62	$22,620,437.57	$31,253,358.19		
5	(64,292,511.05)	$8,848,743.63					$8,848,743.63	$23,185,948.51	$32,034,692.14		
6	(55,222,548.82)	$9,069,962.22					$9,069,962.22	$23,765,597.22	$32,835,559.44		
7	(45,925,837.54)	$9,296,711.28					$9,296,711.28	$24,359,737.15	$33,656,448.43		
8	(36,396,708.48)	$9,529,129.06					$9,529,129.06	$24,968,730.58	$34,497,859.64		
9	(26,629,351.19)	$9,767,357.29					$9,767,357.29	$25,592,948.84	$35,360,306.13		
10	(16,617,809.97)	$10,011,541.22	-2.9%	68,666,068.42	($37,763,931.58)		$10,011,541.22	$26,232,772.56	$36,244,313.78		
11	(6,355,980.22)	$10,261,829.75					$10,261,829.75	$26,888,591.88	$37,150,421.63		
12	4,162,395.27	$10,518,375.49					$10,518,375.49	$27,560,806.68	$38,079,182.17		
13	14,943,730.15	$10,781,334.88					$10,781,334.88	$28,249,826.84	$39,031,161.72		
14	25,994,598.41	$11,050,868.25					$11,050,868.25	$28,956,072.51	$40,006,940.77		
15	37,321,738.37	$11,327,139.96	3.8%	97,270,532.27	($9,159,467.73)		$11,327,139.96	$29,679,974.33	$41,007,114.29		