TRANSFORMING MUNICIPAL SOLID WASTE INTO ENERGY

SOCIAL AWARENESS, EDUCATION, AND POLICY

A Thesis Prospectus
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Bachelor of Science in Chemical Engineering

By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Polymers are materials that can be synthetically produced by chemical engineers and chemists to serve a specific purpose. These materials have specific properties such as viscoelasticity, tensile strength, color, and transparency, which depend on their molecular configuration. Because of their special properties and ability to perform different functionalities, polymers are widely used industrially and can be part of multiple applications. Such applications are found in the fields of aerospace, automotive, electronics, packaging, and medical devices (Brinson & Brinson, 2008). Even though polymers are versatile, single-use plastic such as polyethylene is used excessively in many applications including plastic bags, straws, water bottles, and packaging. The excess use of these polymers is the main source of environmental plastic waste, which composes 40% of the total plastic produced every year (Parker, 2019). Single-use plastics don't degrade over a reasonable timescale, but rather transform into toxic microplastics that remain in our ecosystem for hundreds and even thousands of years (O'Neill, 2018). According to the United States Environmental Protection Agency report (2019), only 9% of plastic waste is recycled because sorting plastic is very challenging and expensive compared to simply producing more plastic. Meanwhile, 75% of plastic produced end up in landfills. Given current rates of plastic waste generation and projections of future plastic use, finding ways to reprocess and transform this immense waste into energy is critical for the healthy functioning of the planet and its inhabitants.

Another important component of addressing the problem of environmental plastic waste is the social human factor: awareness, education, and policy. Many Americans remain uneducated about the problem of plastic waste management. Until recently, the United States sold millions of tons of single-use plastic trash to China to be recycled into new products every year, representing 70% of the world's plastic waste. However, in January 2018, China's

government banned almost all plastic waste imports through the "National Sword" policy (O'Neill, 2018). Since then, no new regulations on plastic production, consumer use, or management have been set by the U.S. government to deal with the growing problem of domestic plastic waste. The STS topic is closely related to the technical project because of the impact of social behavior on environmental pollution. The excessive use of single-use plastic by people increases plastic waste substantially. The solution to the problem requires a two-pronged approach, combining technical solutions on one hand, and social, educational, political efforts on the other hand.

Table 1 shows the four phases of the project, spanning from early November, 2019 through late March, 2020. The tasks associated with the four phases are the Design Basis, Proposal, Progress Report, and the Final Report. The Design Basis (phase 1) includes a full report containing details about the feedstock, basic process scheme, and the products of the process. The Proposal (phase 2) will contain basic economic motivation and design basis. Progress Reports (phase 3) will be provided every three weeks to share the progress of the project before the completion of the Final Report (phase 4) at the end of the semester.

Task Name	Q4			Q1		
	Oct	Nov	Dec	Jan	Feb	Mar
Design Basis						
Proposal						
Progress Report						
Final Report						

Table 1: Project Timeline: The table gives a rough estimate of the time needed to complete the required work to design the project. (Hussein, 2019)

TRANSFORMING MUNICIPAL WASTE INTO ENERGY

The technical project will investigate a method of reducing municipal solid waste (MSW) contaminating landfills. The United States lacks efficient techniques of waste separation and relies on single-stream recycling processes, in which all of the recyclables are placed in the same receptacles. Of the 633 recycling facilities in the country, less than 10% of recycled materials enter the recycling stream, 15% of recycled materials are burned in waste-to-energy facilities, and the remainder end up in landfills where they accumulate and eventually find their way into the environment, thus contributing to pollution (O'Neill, 2018).

In an effort to address the inadequacy of current plastic recycling programs, this project will repurpose municipal solid waste for the production of hydrocarbon fuels and other energy-abundant materials. The primary end-goal of the design is to reduce the quantity of solid waste that goes to landfills, coupled with carbon capture. A potential secondary effect is the affordable energy-source material, since the components in the feedstock used in the design's energy production, such as plastics, may be obtained for a profit (Al-Salem SM, 2019).

One approach to the waste-to-energy system is pyrolysis, a process that includes a thermochemical conversion of carbonaceous substances to fuel (Eilhann et al., 2019). Rather than producing significant CO_2 emissions, this process utilizes CO_2 to suppress harmful chemical formation (Eilhann et al., 2019). Alternatively, Niu et al. (2013) claim gasification as superior since it increases hydrogen yield by 500% compared to pyrolysis.

MUNICIPAL WASTE CONVERSION TO SYNGAS

The first step of the proposed process will involve gasification; the process of converting carbonaceous materials, such as plastics in MSW, into a gaseous and solid product called synthesis gas, or "syngas" by heating them. Syngas is a mixture of carbon monoxide, methane, hydrogen gas, carbon dioxide gas, and heavier hydrocarbons. As illustrated in figure 1, p.5, the syngas will undergo a water-gas shift reaction to produce fuel that will be fed to a solid oxide fuel cell (SOFC) combined with a gas turbine and organic Rankine cycle to generate electricity. The combined cycle is superior to the standalone SOFC due to the heat waste capture: the organic rankine cycle captures residual heat from the gas turbine, which captures heat from the fuel cell. The three units in series makes the process 8-12% more efficient than the single solid oxide fuel cell (Ragini et al., 2018).

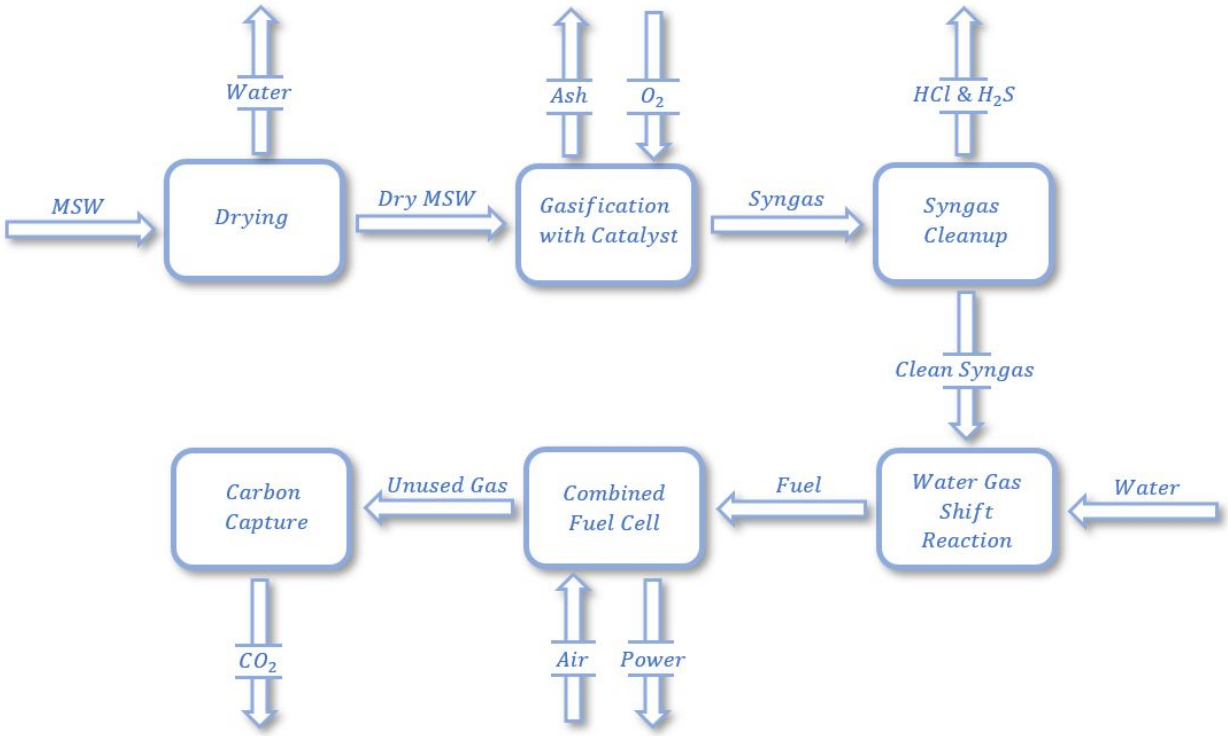

Figure 2: Municipal Waste Recovery to Energy Scheme: The figure describes the process of municipal waste recovery into energy including a gasifier, water gas shift reaction, combined fuel cell, and carbon capture. (Bahati, 2019)

CARBON DIOXIDE CAPTURE

During gasification, carbon dioxide gas is normally vented from the syngas to the atmosphere as it is not required to generate electricity. For this project, carbon-capturing technology in which passing carbon dioxide through absorption/stripping columns that will be used alongside the gasification to prevent carbon dioxide emissions into the atmosphere as well as making the overall process more sustainable. The carbon dioxide recovered will be stored and sold. Ash formed from the gasification chamber will be collected and treated for proper disposal (Ardolino et al., 2018).

Project Personnel are Elias Azar, Kevin Bahati, Ally Hermans, and Naseem Hussein, fourth-year students in the Chemical Engineering department at the University of Virginia. The technical project will be developed in the courses of Process, Synthesis, Modeling & Control, and Chemical Engineering Design over two semesters, directed by Professor Eric Anderson in the Chemical Engineering department at the University of Virginia. The project will require the use of Aspen Plus simulation software, a computer program used by chemical engineers to design chemical processes. Economic analysis and research methods to recover and efficiently reprocess municipal solid waste will also be provided, as well as the implementation of a safe plant environment for the production of energy. By the end of March 2020, the project design report will be delivered with an estimation of the process, cost, and profit.

SOCIAL AWARENESS, EDUCATION, AND POLICY

The ongoing overuse of single-use plastic by society has resulted in a stockpile of plastic waste that will remain in the environment for longer than its intended timescale. As a result, plastic waste is now a major reason for a series of environmental issues including air pollution, microplastic toxicity, and bacteria growth (O'Neill, 2018). The STS topic focuses on finding solutions that would help decrease the use of single-use plastic by society, as well as proposing effective ways to educate consumers and influence corporate producers of plastic. Social pressure is a proven method of changing consumer behavior (in this case, the consumption, use, and disposal of plastic products), and targeted civic pressure can likewise alter industrial plastic production on the corporate level (Durant & Lucas, 2018).

ALTERING CONSUMER BEHAVIOR AROUND PLASTIC WASTE

Pacey's Triangle of Technology Practice (1983) explains that any technology designed is affected by three aspects: technical, cultural, and organizational. Each branch participates in shaping the development of that technology. When approaching solutions to a technical problem, it is necessary to first understand the origins and compounding factors of that problem. Figure 3, p.8 explains the relationship between the technical research project, organizational and cultural aspects of plastic product design.

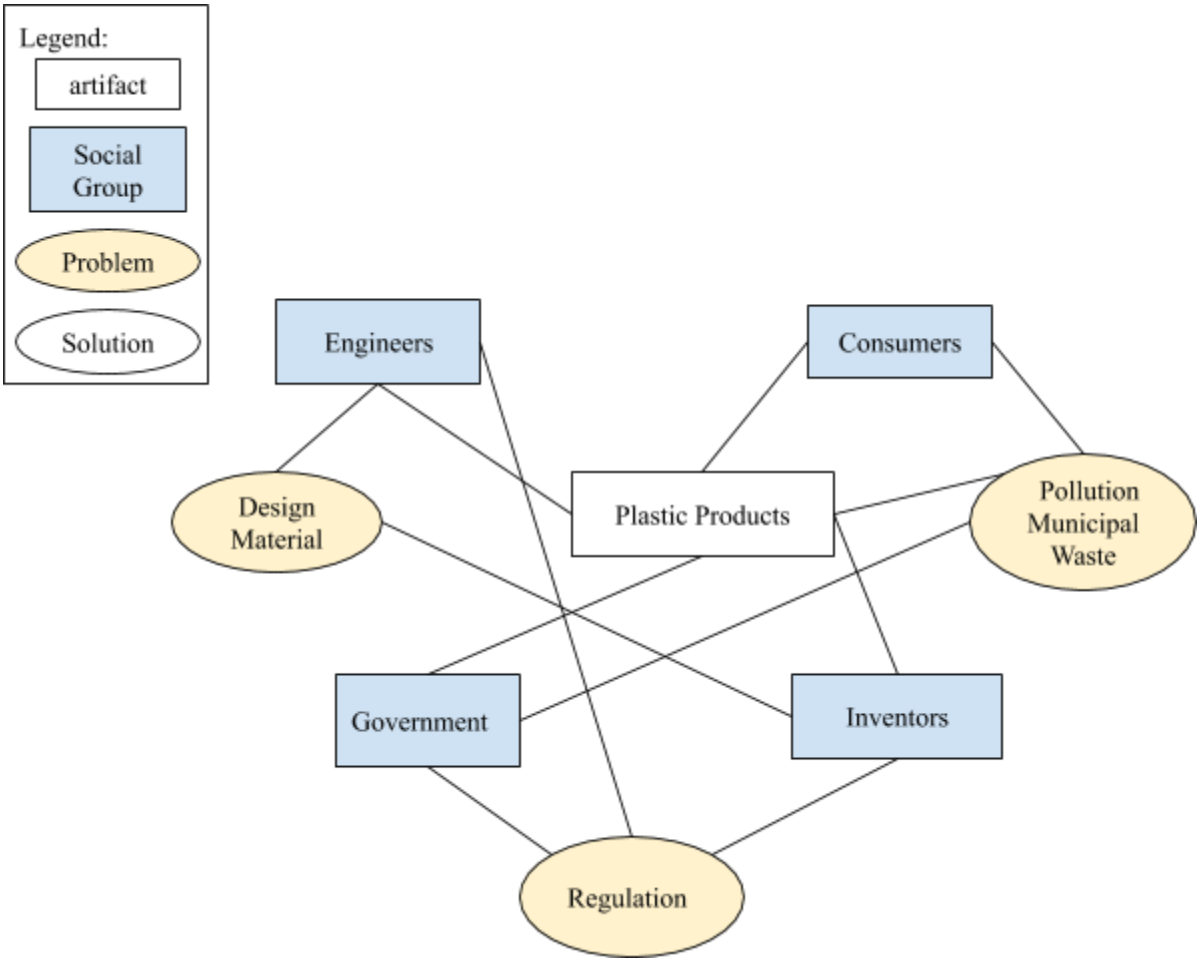

Figure 3: Technology Practice Effect on Increasing Municipal Waste in Landfills based on Pinch and Bijker Models: This diagram explains the relationship between the artifact, social groups, and the problem. (Adapted by Naseem Hussein from Pinch and Bijker, 1987)

A sample solution model can be designed for the pollution problem by analyzing the main sources of the problem, including the design, regulation, consumer behaviors, and waste-to-energy recovery projects. Figure 4, p.9 explains one possible solution to the pollution problem.

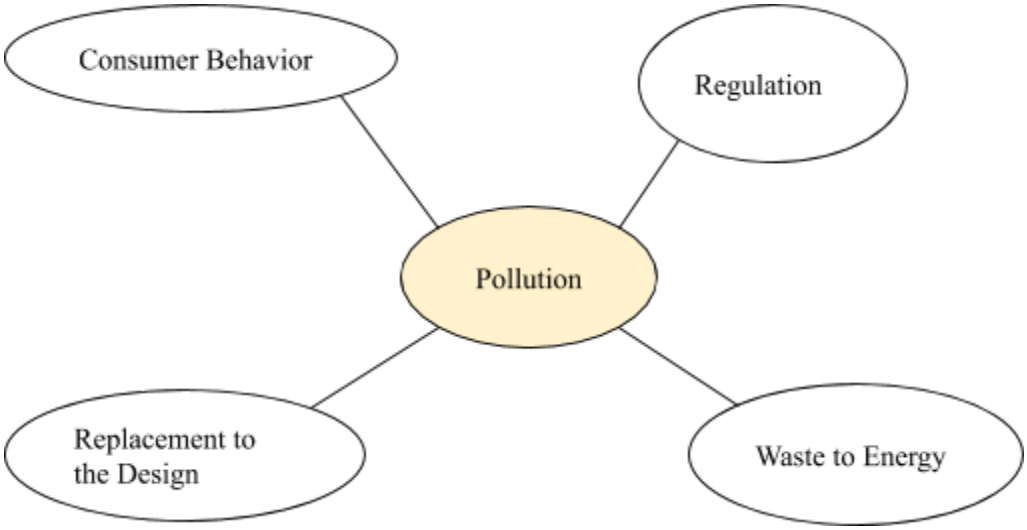

Figure 4: Solution Model to the Pollution Problem based on Bijker and Pinch Models: the diagram explains the solution to the pollution problem based on the factors that created the problem. (Adapted by Hussein from Pinch and Bijker, 1987)

SOCIAL RESEARCH AND WASTE MANAGEMENT

An Australian study by Eagle et al (2016) addressed specific behavioral change interactions based on before-and-after awareness of environmental issues. Using social marketing strategies to develop activities to change or maintaining people's behavior, the study focused on understanding the relationship between "The Person" and "Behavior." The *person* category included communities, citizens, consumers, customers, clients, patients, professionals, and politicians, while the *behavior* category included what people do, an examination of why they do it, influences and influencers, and incentives and barriers. It was concluded that social marketing principles offer promise in changing social behavior, but there is a need to investigate the advantages of various theoretical foundations to aid the design and implement the interventions (Eagle et al., 2016).

Another study done in the community of Lake Erie, Ohio, investigated the importance of preventing plastic waste from reaching the water's edge by testing the obstacles to and benefits of improved consumer management of two common sources of plastic waste—plastic bags and plastic water bottles (Barlotta & Hardy, 2018). Results of the study indicated that residents of the Lake Region of northeast Ohio were willing to change their behaviors in order to reduce plastic waste and were open to the idea of banning plastic bags and plastic water bottles. Additionally, the study found that financial motivation was an effective means of influencing behavioral changes (Barlotta & Hardy, 2018). Unfortunately, despite some local communities' efforts to raise awareness of plastic waste's impact on the environment and green capitalism's recognition of the importance of behavioral change, there are currently no serious steps in place to redirect the legislation towards enforcing green innovation in manufacturing (Durant & Lucas, 2018).

THE EFFECT OF RELIGION ON LEGISLATIVE PROGRESS

McCright & Dunlap (2010) argued that religion has an influence on plastic waste management in the United States. Based on anti-reflexivity research, efforts by the American Conservative Movement (ACM) have helped undermine climate science and policy in the United State over the past two decades. The study of anti-reflexivity describes a variety of attacks by the ACM on the credibility of the environmental research, which has resulted in the discreditation of environmental science, especially among conservative Americans, and has also had the effect of suppressing legislative efforts towards increased environmental protections. The research further concluded that the consequences of the plastic waste crisis are directly related to a lack of governmental regulations and environmental protection policies (McCright & Dunlap, 2010).

Solving the problem of single-use plastics and their associated waste is an environmental and humanitarian necessity. This project seeks to achieve a solution to this urgent problem through both technological innovation and social change. The technical topic will decrease the current municipal solid waste in landfills that represent 75% of plastic waste, while the STS topic will focus on finding solutions related to cultural behavior, governmental legislation, and education. In order to eliminate the problem of global plastic waste and management, it is critical that both technological and social perspectives are understood and addressed in order to establish a sustainable solution.

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