Socio-technical Problem

About one hundred million tons of plastics are produced annually, and the global market size for plastics is projected to grow at a compound annual growth rate of 4% leading up to 2025 (World Wildlife Fund [WFF], 2019; Grand View Research, 2019). This is mainly because plastics possess ubiquitous properties due to their rich chemistry that allows for their various applications– plastics are used to cut fuel consumption in different means of transportation such as cars and aeroplanes, they are used in the manufacture of electrical and electronic equipment, and are also widely used in the construction industry and for packing materials. The plastics industry also plays a substantial role in sustaining the global economy; in America alone, plastic bags sustain 39000 jobs (Plastics Industry Association [PLASTICS], n.d.). On average, plastics are used just once and thrown away, and they degrade very slowly and are also generally non-biodegradable (Plastic Oceans International, n.d.). This leads to an exponential growth of pollution that fills up landfills and eventually finds its way into the environment; eight million tons of plastics are dumped into oceans annually (Plastic Oceans International, n.d.). Plastic pollution poisons marine life, disrupts human hormones, contributes to the spread of cancer, and poses great risks to prostate health (Royte, 2018; Center for International Environmental Law, n.d.). With the market for plastics expected to grow, production of plastics can be expected to grow with it, increasing the likeliness of plastic pollution (Senet, 2019). Due to this, technologies that combat plastic pollution will be needed even more than they are currently needed. The lifecycle of plastics, and plastic waste management in particular, enormously contributes to greenhouse emissions that warm our planet; plastic waste incineration is expected to increase greenhouse gas emissions by 49 million metric tons by 2030 and 91 million metric tons by 2050 if the previously mentioned growth in plastic production occurs (Bauman, 2019). Various solutions have been proposed to address the many problems associated with plastics and plastic waste, including radical solutions such as the total ban of plastic production and more economical technologies such as hydraulic fracturing, the process of injecting water, sand, and chemicals under high pressure in a fossil fuel-rich rock to extract oil and gas from it, which are responsible for the production of plastics (Kelly, 2019). To address this problem, I will design a chemical processing facility that will convert municipal solid waste, which includes plastic waste, to energy. Knowledge gained from this design will lay the foundation for the design of a general-purpose chemical processing facility that can convert plastic waste from any source, such as landfills and oceans, into energy that can power large communities.

However, it is important to keep in mind the science, technology, and society (STS) aspect of the problem of plastic pollution, which is the network of actors needed to combat the problem. The network of actors, not just technical but also social, environmental, and legal, that have to work together to reduce or stop plastic pollution, is fundamental (Latour, 2005). Considering this, I will use the science, technology, and society (STS) framework of actor-network theory to examine why and how Rwanda, a developing country in East Africa, has managed to successfully take up radical measures of banning plastics to combat the environmental risks that plastics pose. With this case study of an approach to plastic pollution, I will show that a specific approach to stopping plastic pollution can only thrive in a specific network; this will elaborate how fundamental a network of actors associated to a technology is to the prosperity of the technology.

Below, I elaborate the technical aspect of my solution and the associated science, technology, and society (STS) study.

Transforming Municipal Solid Waste to Energy

The technical project will investigate a method for reducing plastic waste. The United States lacks efficient techniques of waste separation and relies on single-stream recycling processes, processes in which all recyclables are combined into a single receptacle. 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).

To address this problem, this project will repurpose municipal solid waste (MSW) 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 price reduction of energy-source material, since the components in the feedstock used in the design's energy production, such as plastics, may be obtained for less than their industrial price (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.

The first step in the proposed process will involve gasification (see *Figure 1* below for a block flow diagram of the entire process). Gasification is the process of converting carbon-containing materials in the presence of heat, such as plastics in MSW, into a gaseous product called synthesis gas, or "syngas." Syngas is a mixture of carbon monoxide, methane, hydrogen gas, carbon dioxide gas, and heavier hydrocarbons. 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 a single solid oxide fuel cell, implying less fuel consumption and pollutant emissions. (Ragini et al., 2018). Carbon dioxide gas produced from gasification will be trapped via carbon-capturing, thus making the overall process more sustainable. The carbon dioxide recovered will be stored and sold. Ash formed in the gasification chamber will be collected and treated for disposal or converted to commercial material (Ardolino et a.l., 2018).

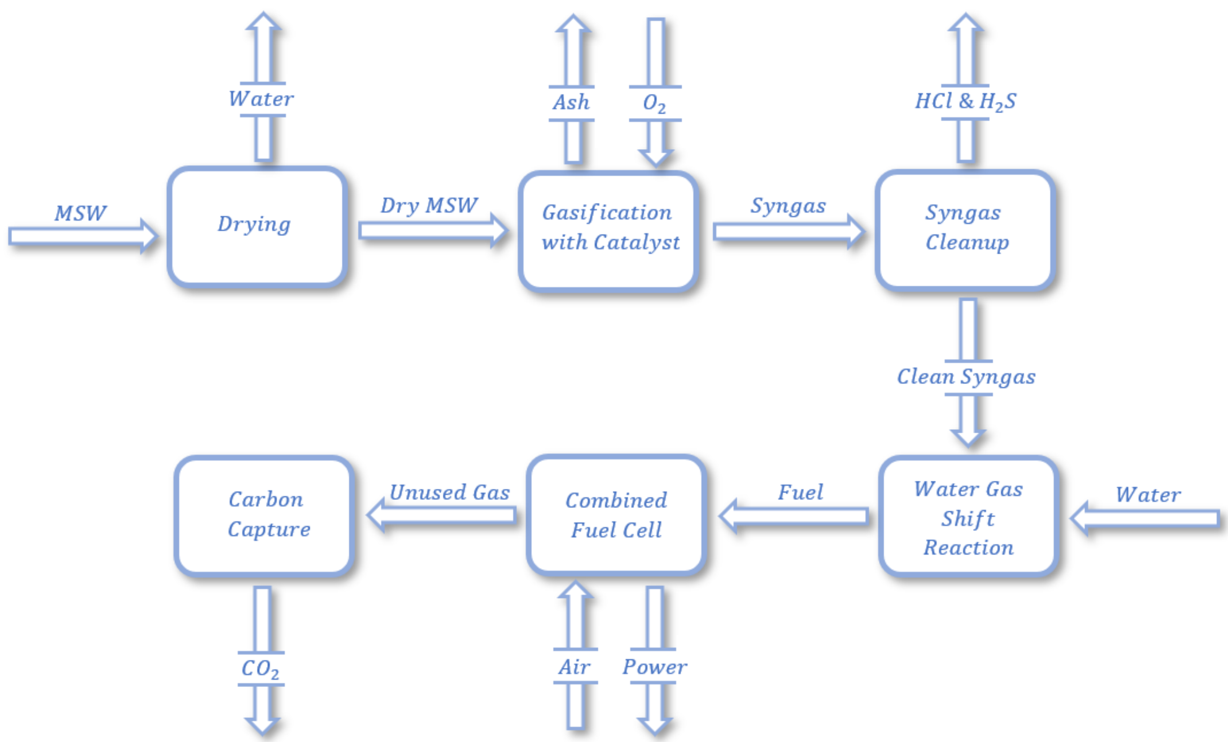

Figure 1: Block flow diagram of the overall waste-to-energy process (Bahati, 2019)

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 MSW 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.

Plastic Waste Management Approaches and Sociopolitical and Socioeconomical Factors.

Since 2008, Rwanda, a developing country in the East African region, has placed an almost total ban on plastics; in the country, the importation, sale, and use of plastic bags is generally illegal and traffickers caught having illegal plastics are liable and can be fined or even jailed. This approach to curbing plastic pollution in Rwanda has proved to be socioeconomically effective (Behuria, 2019). In the United States, the epitome of development, use of plastics is yet to be banned in the entire country in a manner any similar to that of Rwanda. Only ten states, including Arizona, Florida, Iowa, Idaho, Michigan, Minnesota, Mississippi and Wisconsin, have passed preemptive bans on banning plastic bags (Jacobo, 2019). And plastic production is expected to increase in the country due to the forecasted boom in hydraulic fracturing technology, which is largely responsible for the production of materials that are feedstocks in the production of plastics (Earthworks, n.d.; Kelly, 2019). Considering that Rwanda and United States are two countries with very different sociopolitical and socioeconomic nature, the current state of each country's approach to managing plastic pollution is strongly indicative that socioeconomic and sociopolitical factors strongly affect the approach that can be employed to manage plastic waste and pollution. By recognizing this, the socioeconomic and sociopolitical barriers to reducing and preventing plastic pollution can be determined, and solutions on how to get past them can be developed.

Considering that countries with varying socioeconomic and sociopolitical nature employ different approaches to managing plastic pollution, I argue that socioeconomic and sociopolitical factors are essential in developing and implementing an approach to manage plastic pollution. To establish this argument, I will use the framework of actor-network theory (ANT) to examine why Rwanda's anti-plastic pollution network has been successful. Actor-network theory describes the relationship between technology and society by examining power dynamics in heterogeneous networks – networks comprised of both human and non-human actors (Callon, 1987; Latour, 2005). The ANT framework will be used because the analysis will be centered on how a network of actors, not just technical but also social, environmental, legal, and many more can shape different approaches to solving the problem of plastic pollution. Knowledge from this study will guide the development of effective plastic waste management technologies.

Conclusions

The technical report will deliver the design of a chemical processing facility that converts the plastic waste to energy. Knowledge gained from this design will lay the foundation for the design of a general-purpose chemical processing facility that can convert plastic waste from any source to energy that can power large communities. The STS research paper will use the concept of actor-network theory to establish the role that the network of social, political, and economic factors plays in influencing approaches to plastic waste management in Rwanda and the United States, two countries that are of varying sociopolitical and socioeconomical nature.

Results from the technical work will provide a solution to the broad socio-technical issue of plastic waste management by delivering the design of a pilot chemical processing facility that converts plastic waste into energy, and eventually guide the design of a larger-scale facility that can power big communities. Findings from the STS research paper will shed light on how social, economic, political, and other factors influence approaches to plastic management, thus laying the foundation for the design of socioeconomic approaches to and technologies for plastic waste management.

Word Count: 1705

References

Ardolino, F., Arena, U., Astrup, T. F., Lodato, C. (2018, December 15). Energy recovery from plastic and biomass waste by means of fluidized bed gasification: A life cycle inventory model. *Energy*, 165, 299–314. doi:10.1016/j.energy.2018.09.158

Al-Salem, S. M., Baeyens, J., & Lettieri,J. (2009, October). Recycling and recovery routes of plastic solid waste (PSW): A review. *Waste Management*, *29*(10), 2625-2643. doi:10.1016/j.wasman.2009.06.004

Bahati, K., (2019). Block flow diagram of the overall waste-to-energy process. The University of Virginia. Chemical Engineering Department. Charlottesville VA, 22903

Bauman, B. (2019, August 23). How plastics contribute to climate change. *Yale Climate Commissions*. Retrieved October 29, 2019, from https://www.yaleclimateconnections.org/2019/08/how-plastics-contribute-to-climate-change/.

Behuria, P. (2019, February). The comparative political economy of plastic bag bans in East Africa: why implementation has varied in Rwanda, Kenya and Uganda [Abstract]. *Global Development Institute-The University of Manchester*. Retrieved October 29, 2019, from https://www.gdi.manchester.ac.uk/research/publications/gdi-working-papers/2019-037/.

Callon, M. (1987). Society in the making: the study of technology as a tool for sociological analysis. Retrieved November 11, 2019, from, https://collab.its.virginia.edu/access/content/group/

4d24a806-a6c8-4f36-a135-15f1f498d86a/Readings/Callon.SocietyintheMaking.pdf

Center for International Environmental Law (n.d.). Plastic and human health: A lifecycle approach to plastic pollution. (n.d.). Retrieved October 29, 2019, from https://www.ciel.org/project-update/plastic-and-human-health-a-lifecycle-approach-to-plastic-pollution/.

Earthworks (n.d.). Fracking for Plastic. *Earthworks*. Retrieved October 29, 2019, from https://earthworks.org/issues/fracking-for-plastic/.

Eilhann, E.K., Kim, S., Lee, J. (2019 May). Pyrolysis of waste feedstocks in CO2 for effective energy recovery and waste treatment. *Journal of CO2 Utilization*, *31*, 173-180. doi:10.1016/j.jcou.2019.03.015

Grandview Research (2019, January). Plastic market size worth $721.14 billion by 2025: CAGR: 4.0%. Retrieved October 29, 2019, from https://www.grandviewresearch.com/press-release/global-plastics-market-analysis.

Harris, W. (2018, June 28). How long does it take for plastics to biodegrade? Retrieved October 29, 2019, from https://science.howstuffworks.com/science-vs-myth/everyday-myths/how-long-does-it-take-for-plastics-to-biodegrade.htm.

Jacobo, J. (2019, June 6). Despite war on plastic, study shows only few states have banned plastic bags. Retrieved October 29, 2019, from https://abcnews.go.com/Health/war-plastic-study-shows-states-banned-plastic-bags/story?id=63529555.

Kelly, S. (2019, May 15). Plastics industry on track to burn through 14% of world's remaining carbon budget: new report. *Desmog*. Retrieved October 29, 2019, from https://www.desmogblog.com/2019/05/15/plastics-industry-climate-change-emissions-oceans-ciel-report.

Latour, B. (2005). Reassembling the social: an introduction to actor-network-theory. *Oxford: Oxford University Press.*

Martinko, K. (2019, February 22). Plastic is toxic at every stage of its life cycle. Retrieved October 29, 2019, from https://www.treehugger.com/plastic/plastic-toxic-every-stage-its-life-cycle.html.

Niu, M., Huang, Y., Jin, B., Wang, X. (2013, September 6). Simulation of syngas production from municipal solid waste gasification in a bubbling fluidized bed using Aspen Plus. *Ind. Eng. Chem. Res. 52*(42), 14729-15006. doi:10.1021/ie400026

O'Neill, K. (2018, December 4). The plastic waste crisis is an opportunity for the U.S. to get serious about recycling at home. Retrieved from https://theconversation.com/the-plastic-waste-crisis-is-an-opportunity-for-the-us-to-get-serious-about-recycling-at-home-93254

Plastics Association Industry(n.d.). District fact sheets: Michigan fact sheet. Retrieved October 29, 2019, from https://www.plasticsindustry.org/factsheet/michigan.

Plastics Industry Association (n.d.). How plastic bag bans impact the economy. Retrieved October 29, 2019, from https://www.thisisplastics.com/economic-impact/how-plastic-bag-bans-impact-the-economy/.

Plastic Oceans International (n.d.). The facts are overwhelming. (n.d.). Retrieved from https://plasticoceans.org/the-facts/

Ragini, S., Onkar S. (2018, September 1). Comparative study of combined solid oxide fuel cell-gas turbine-Organic Rankine cycle for different working fluid in bottoming cycle.

ScienceDirect, *171*. Retrieved from https://www.sciencedirect.com/science/article/pii/S0196890418306186

Royte, E. (2018). We know plastic is harming marine life. What about us*? National Geographic* Retrieved November 11, 2019, from https://www.nationalgeographic.com/magazine/2018/06/plastic-planet-health-pollution-waste-microplastics/

Senet, S. (2019, June 5). Plastic production on the rise worldwide but slowing in Europe. *Euractiv*. Retrieved October 29, 2019, from

https://www.euractiv.com/section/energy- environment/news/while-global-plastic-production-is-increasing-worldwide-it-is-slowin-down-in-europe/.

World Wide Fund (2019). Plastic waste and climate change - what's the connection? Retrieved from https://www.wwf.org.au/news/blogs/plastic-waste-and-climate-change-whats-the-connection#gs.ams7vg.