Thesis Project Portfolio

Producing a Bioplastic from Biodiesel Waste: Poly(hydroxybutyrate) using Crude Glycerol

(Technical Report)

Plastics in Fashion: How Consumer Culture Obscures the Petrochemical Life Cycle

(STS Research Paper)

An Undergraduate Thesis

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Executive Summary

When I began my undergraduate studies in chemical engineering, I hoped to answer how our society can use chemical engineering to solve global crises: climate change, public health, world hunger. My undergraduate thesis portfolio is a dive into the deep-end of another human-made generational challenge. Plastic is a pillar of modern living – no material is as simultaneously revered and despised. As always, it's clear actions speak louder than words because plastic use far outweighs any negative public sentiment. In an attempt to provide an eco-friendly replacement to low-value, single-use plastics, my technical project with the sustainable materials capstone group focuses on designing a plant to manufacture poly(hydroxybutyrate) (PHB), a bio-sourced, degradable plastic produced from biodiesel waste. The technology to produce PHB is feasible, but the economic viability is not. To be frank, we anticipated this result, so I positioned my thesis research to answer why a sustainable project, such as ours, is still a fantasy. My research question asks how consumer culture obscures petrochemical life cycles and who is responsible for leading the shift away from plastic dependence. Throughout the research paper, I explore how fossil fuels drive much more than our cars. Petrochemicals, derived from fossil fuels, are inextricably linked to contemporary society because they are the drivers of many consumer industries, such as agriculture and fashion. However, consumerism left unchecked is a dangerous threat to our environment and society.

Our technical design project encompasses multiple facets of sustainability. The low-value raw material is crude glycerol, which is a waste product from the biodiesel industry. Our plant resides in Iowa and is equidistant from three biodiesel manufacturers, so we can limit transportation costs and emissions. Through applying inherently safer design principles, our process uses few additional and relatively benign chemicals as compared to traditional plastic manufacturing. The main chemical process is a fermentation using the non-GMO

microorganism, *Cupriavidus necator*. This bacterium produces our product, PHB, as inclusion bodies when its access to nitrogen is limited. The downstream processes consist of only mechanical separations of PHB from the bacteria, rather than chemical extractions. The final aspect of sustainability is the product itself. PHB does not need an industrial composting facility to degrade, and the ability of *C. necator* to produce PHB from waste glycerol makes the material a link in the circular economy. Unfortunately, when our product is sold at a market price of $4.50/kg as a replacement for non-renewable single-use plastics, our plant design loses money every year. Some viable economic scenarios exist by using government subsidies or making a higher value, medical grade PHB. Ultimately, the design as is would not be a sustainable investment for replacing single-use plastic.

Petrochemicals' invisible integration into society contributes to a number of environmental crises, such as plastic waste, fossil fuel consumption, and marine pollution. My thesis research aims to uncover how a consumer culture centered around convenience obscures the life cycle of petrochemicals and their derived materials. Through applying the Science, Technology, and Society (STS) framework of co-production, I find that the development of uses for plastic and other petrochemical materials are in response to problems they create. Recently, the fast fashion industry has become a beneficiary of this same pattern. After performing a case study on Shein's rise to becoming a fast fashion giant, I reach the conclusion that a shift away from convenience culture has to come from both producers and consumers. My research contributes to the field of STS through highlighting a path towards a society no longer deeply dependent on fossil fuels.

Through my work on both projects, my mindset regarding sustainability expanded and contracted. From the technical end, it was disappointing to find that a project acknowledging all

aspects of a material's life cycle could fail. On the other hand, my thesis shed light as to why our project would not fit into contemporary society. A simple replacement of a petrochemical-derived plastic with a bio-sourced plastic does not take into account the various social, economic, and cultural factors that made the original plastic useful. If a swap for more eco-friendly materials is not the answer to the massive waste problem, then what do we change? Plastic production and consumption have been on an upward trajectory since its advent, and the petrochemical industry's shift to focus developing countries will only continue this trend. Continuous excess consumption is not a benign behavior, which begs the conclusion that our economic system is fundamentally unsustainable. Sustainability is not a green-labeled product or a scapegoat for producing more. Sustainability is a way of life, one that is not unfamiliar to indigenous societies across the globe. Listening to and learning from these cultures would catalyze the essential shift from the present consumer culture to a future sustainability culture.