Thesis Project Portfolio

Supercritical Biodiesel Production Process from Waste Cooking Oil

(Technical Report)

How Policy and Consumer Incentives Drive Biodiesel Adoption

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2025

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Sociotechnical Synthesis

My technical capstone project and STS research paper address the same fundamental challenge: understanding what biodiesel needs to become a mainstream alternative to petroleum diesel. During the technical portion of the capstone project, my team developed an efficient biodiesel production facility using waste cooking oil and supercritical transesterification. This method eliminates the drawbacks of traditional catalyst-based processes while proving economically viable when supported by green policies such as the national biodiesel tax incentive. Yet as we refined the technical design, we recognized that even the most optimized production system would fail without systemic changes beyond the plant. This insight shaped my STS research, where I applied the Sociotechnical Transitions Framework to examine the political, economic, and social barriers limiting biodiesel adoption in the U.S. The complementary nature of these papers highlights the problems of renewable energy as a whole. Successful energy transitions require more than innovation. They demand coordinated policy, infrastructure investment, and public engagement. Without these elements, technological advances remain confined to small-scale applications. Processes like ours would fall through the cracks without sufficient consumer demand to provide a platform for scale-up. Together, these projects highlight that solving complex energy challenges requires both engineering expertise and sociopolitical understanding.

This capstone project presents the technical and economic design of a biodiesel production facility capable of generating approximately 9,500 tonnes per year of B100 biodiesel from waste cooking oil (WCO), with pharmaceutical-grade glycerol as a valuable byproduct. The process enhances sustainability by utilizing a waste feedstock and reducing dependence on fossil resources. The plant employs supercritical methanol to eliminate the need for catalysts, allowing the use of low-quality WCO and simplifying reactor operation. Conversion of WCO to biodiesel occurs via two simultaneous pathways within a plug flow reactor: hydrolysis followed by esterification of free fatty acids (FFAs), and direct transesterification. Downstream, unreacted methanol and propane co-solvent are recovered, and the final biodiesel and glycerol products are purified to meet ASTM D6751-24 and USP standards. Economically, the process is viable with a $1/gallon biodiesel tax credit, achieving an internal rate of return (IRR) of 13.9% and a net present value (NPV) of $67.1 million. However, without the tax credit, the IRR drops to 5.6%, making the project less attractive. Given the economic sensitivity and technical uncertainties related to kinetic modeling, we recommend constructing a pilot-scale reactor to validate assumptions before committing to full-scale implementation.

My research paper investigates why biodiesel remains a marginal fuel in the U.S. despite its environmental advantages and technical viability. My capstone work on supercritical transesterification revealed a critical lesson in that production breakthroughs mean little without systemic support. The Sociotechnical Transitions Framework helps explain this disconnect; while the U.S. excels at innovation, it lags in policy stability, consumer education, and infrastructure development. Comparisons with global leaders prove change is possible. Indonesia’s phased biodiesel mandates and Norway’s consumer incentive programs demonstrate how coordinated action drives adoption. Yet in America, progress stalls as fossil fuel interests exploit policy loopholes and overall public unfamiliarity. The path forward requires alignment across all of these levels. Durable policies must complement technical advances, public awareness campaigns should mirror fueling infrastructure expansion, and industry resistance must be countered through legislative action. Biodiesel’s potential is undeniable, but exploiting its potential requires a redesigned energy ecosystem.

Working on my capstone project and STS research paper at the same time helped me see the full picture in a way that I don't think was possible if I had done them separately. On the technical side, I was really focused on making biodiesel production more efficient. I honed in on science through looking at chemical reactions, reactor design, and cost calculations that correlated with our final process. It felt like we had come up with a pretty solid system, and that should have been enough. But while doing my STS research, I realized that no matter how good the technology is, it won't take off unless the world around it is ready. Policies, infrastructure, and even how people think about fuel all play a huge role. That really shifted how I thought about our technical work, inciting the question, "Who will actually use this?" and "What's standing in their way?" At the same time, doing the technical work kept my STS paper grounded. Instead of writing in vague terms about biodiesel as a concept, I could speak from direct experience. I knew what made the process complex, what made it expensive, and why incentives like tax credits were actually make-or-break for a project like ours. Together, the two projects made me a more well-rounded thinker. I started out focused on the technical side of the renewable energy industry, but I came away with a better understanding of how important systems, people, and policy are in making new technology matter. It taught me that real change doesn't just happen in a lab, it has to happen everywhere.