**Date:** April 9th, 2024  
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Department of Chemical Engineering faculty,

To the chairman and the rest of the committee:

**I am requesting a**transfer from the MS track to the PhD track in Chemical Engineering.

My future doctoral work will pinpoint intersections of economic feasibility and environmental sustainability using integrated agile life cycle assessment (LCA) and technoeconomic analysis (TEA). My work will focus on two commodities where the production of incumbent products have scale but high carbon intensity: meat alternatives, and biofuels. Each require a balance between cost competitiveness and sustainability to effectively substitute for their competition. Both aims investigate economic feasibility or environmental impact. My capability to succeed in this role is evidenced by my past research in the Shi lab, as well as my educational background in bioengineering.

My master’s thesis and its publication spin off (in preparation) utilize life cycle assessment to inform the public about meat alternatives with additives produced via bioreactors. Meat alternatives are processed plant and fungal proteins formulated to emulate meat. One rationale for their consumption is their reduced environmental impact. To enhance adoption and improve verisimilitude to meat, several companies have added bioengineered heme protein to their meat alternatives. Past life cycle assessments of meat alternatives containing heme have determined the impact of the entire product but have not quantified the impact of the heme additive in depth. My work not only elucidated the impact of this additive, but also modeled renewable energy variation in the electricity mix and electricity usage; heme content and production characteristics; agricultural ingredient procurement; and agricultural product usage. Heme has an impact of 117 kg CO2 equivalent per kg of heme, greater than that of ground beef, but not large enough to result in a higher impact for the meat alternative. However, heme production’s impact corresponds to roughly 40% of the global warming potential of the entire product, despite heme protein being only approximately 1% of the product’s mass. Comparisons between electricity consumption and renewables content, versus agricultural ingredient procurement reveal several different avenues for environmental impact reduction. My work in this area was presented at the 2023 Biorenewables Symposium and won third place in the poster presentation contest. However, for future refinement, these potential changes must be examined in the context of the sensitivity of all technical parameters. Integrated life cycle assessment and technoeconomic analysis can help determine both the environmental impact and economic feasibility of further process refinements. I aim to expand upon my prior work with meat alternatives to conduct a global sensitivity and uncertainty analysis of the heme protein production system to better expand upon technical considerations suggested by my manuscript, and how they might be leveraged to improve process environmental impact.

My other area of focus, integrated technoeconomic analysis and life cycle assessment of biofuels, will assess different environmental and technical tradeoffs of process design decisions. To combat climate change, there is a need to transition to lower carbon intensity fuel, to both accommodate current infrastructure, and provide the required energy density for certain modes of transportation. One route of biofuel production is via valorization of ethanol derived from plant biomass. Unlike fermentation from sugars, plant biomass typically requires further degradation before it can be effectively used as a carbon source by microorganisms. Initial cellulosic ethanol plants utilized pretreatment to break down plant biomass into easier to digest oligomers. Pretreatment required either expensive enzymes or more energy intensive processes. To improve the economic viability of the process, pretreatment has been integrated into fermentation via cotreatment. The current design of cotreatment utilizes a bioreactor design that also mills the plant biomass. Due to the sheer stresses and higher temperatures required for plant biomass breakdown, a thermophilic gram-positive bacterium, *A. thermocellus* (also known as *C. thermocellum*), is used to both ferment the oligomers, and also utilize its extracellular cellulase complexes to breakdown the larger cellulose oligomers prior to their utilization as a carbon source. My current and future work will be on developing integrated life cycle assessment and technoeconomic analysis modules for the production of ethanol produced from lignocellulosic biomass. Unlike my work on meat alternatives, the design of the fermentation and valorization processes have not been built at scale, requiring analysis to guide process design decisions. Innovations such as the novel bioreactor design and choice of non-model organism also likely require uncertainty analysis and sensitivity analysis due to uncertainty with potential process improvements. Due to the global decision variable of economic viability, familiarity with all aspects of the process, including fermentation technologies and strain design is needed. My past educational background in bioengineering with a focus on biotechnology, and my master’s degree in bioengineering with a research topic of kinetic models of microbial biochemical networks provides me familiarity with both the process design, and the metabolic networks that need to be rerouted to maximize ethanol yield. I aim to leverage my past knowledge base and work to develop integrated LCA and TEA modules which can take process simulation data, reduce the number of parameters, and provide impact assessments of design changes quickly.

Future work will entail producing agile technoeconomic analysis and life cycle assessment modules to help inform the CBP team of impacts of proposed changes to technical parameters or show the sensitivity of profitability to random variations in contextual parameters. My past work in life cycle assessment and masters’ work provides me with the unique perspective, education, and technical capability to model the effects of these considerations on project profitability and environmental impact.

In light of the capabilities I provide these projects, I wish to continue my work in the Shi lab as a PhD student. Thank you for your consideration and your time.

Sincerely,

Kay Glass