Implementing Life Cycle Assessment to Understand the Environmental and Energy Implications Associated with Biodiesel

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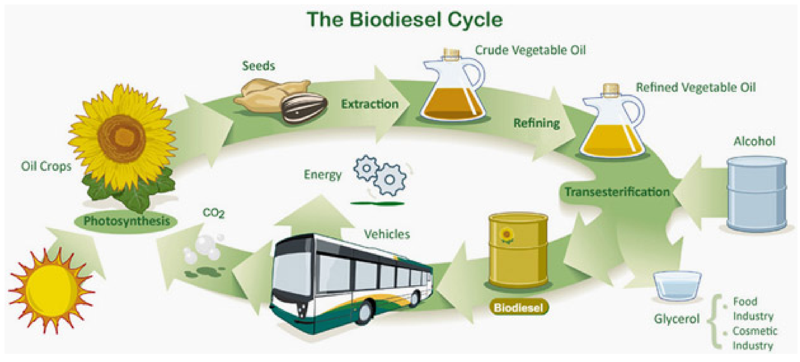
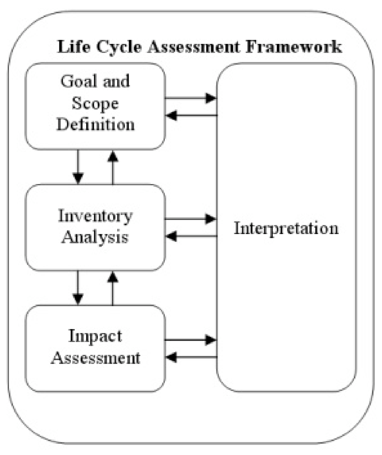
Introduction

Life Cycle Assessment is tool used to evaluate the impacts of a system or a product from cradle-to-grave (raw material extraction, materials processing, manufacture, distribution, use, and disposal or reuse).





An LCA study consists of four main phases:

Step 1: Define the goal and scope of the study.
Step 2: Make a model of the product life cycle with all the environmental inputs/outputs. This is known as the life cycle inventory (LCI).
Step 3: Understand the environmental relevance of all the inputs/outputs. This is referred to as life cycle impact assessment (LCIA).
Step 4: The interpretation of the study.

Abstract

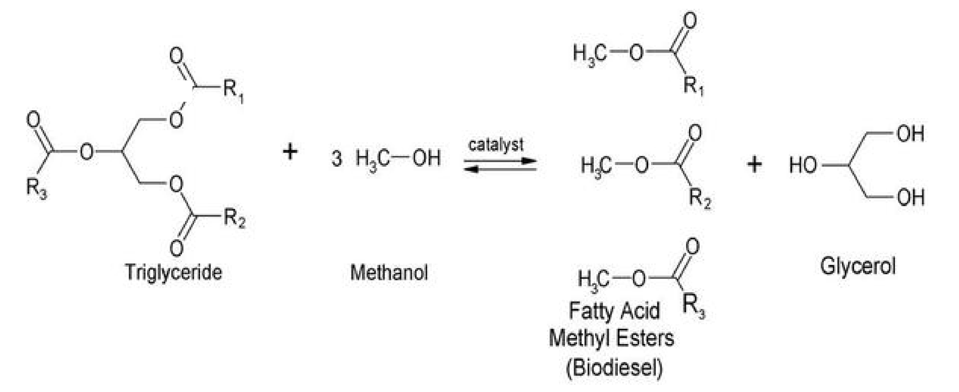


Figure 1. Transesterification Reaction

This project explores the life cycle of biodiesel within the constraints of two system boundaries. The first boundary (see figure 2) may be expanded to encompass the agriculture and processing phases. The second system boundary may be understood to represent the refination of oil feedstock triolein into methyl oleate (see figure1). Using a life cycle assessment software known as Simapro, LCA datasets and computational data from ASPEN are used to evaluate these system boundaries.

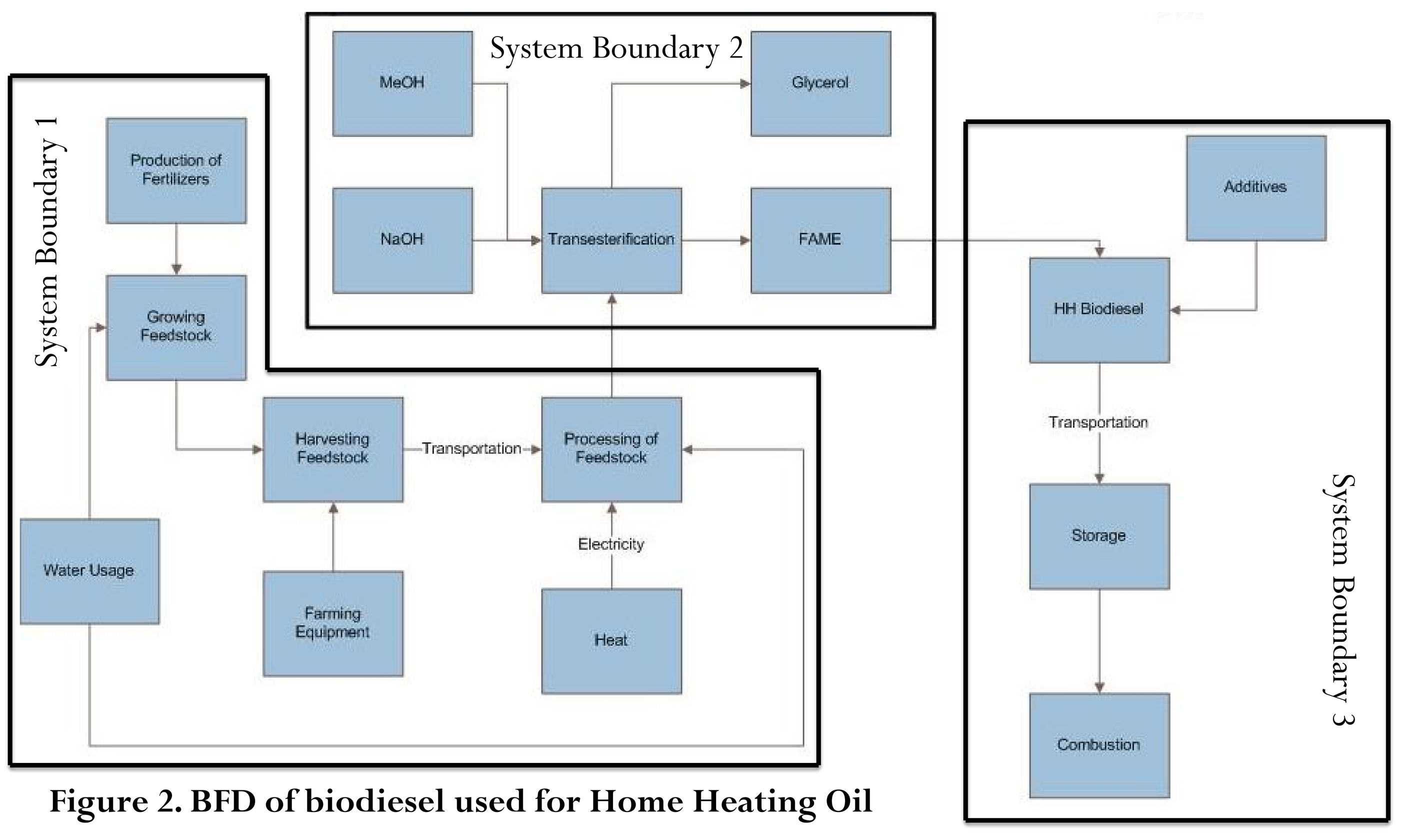


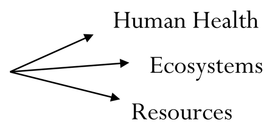
Figure 2. BFD of biodiesel used for Home Heating Oil

Methods

Many methods exist within LCA and the SimaPro software that are tailored to specific impact categories and therefore to specific products or systems. The two that were used for the purpose of this project were:

1.) Cumulative Energy Demand
- Quantifies the energy usage of each unit process attributed to a system

2.) ReCiPe
- Delineates 18 mid-point categories into 3 damage categories



Sources of Error

Due to the nature of proprietary knowledge within the private sector, data for the actual processing of biodiesel is difficult to accurately portray, thus assumptions must be made. Taking this into consideration, SimaPro allows for the classification of each dataset so that a Monte Carlo analysis can be made. Since computer models were used as a guide, they may not fully represent reality. Furthermore, many unit processes remain left out of the entire process simply due to time constraints and difficulty which of course ultimately may mischaracterize the system as a whole.

Conclusion

From the scope of this project, the following may be understood:

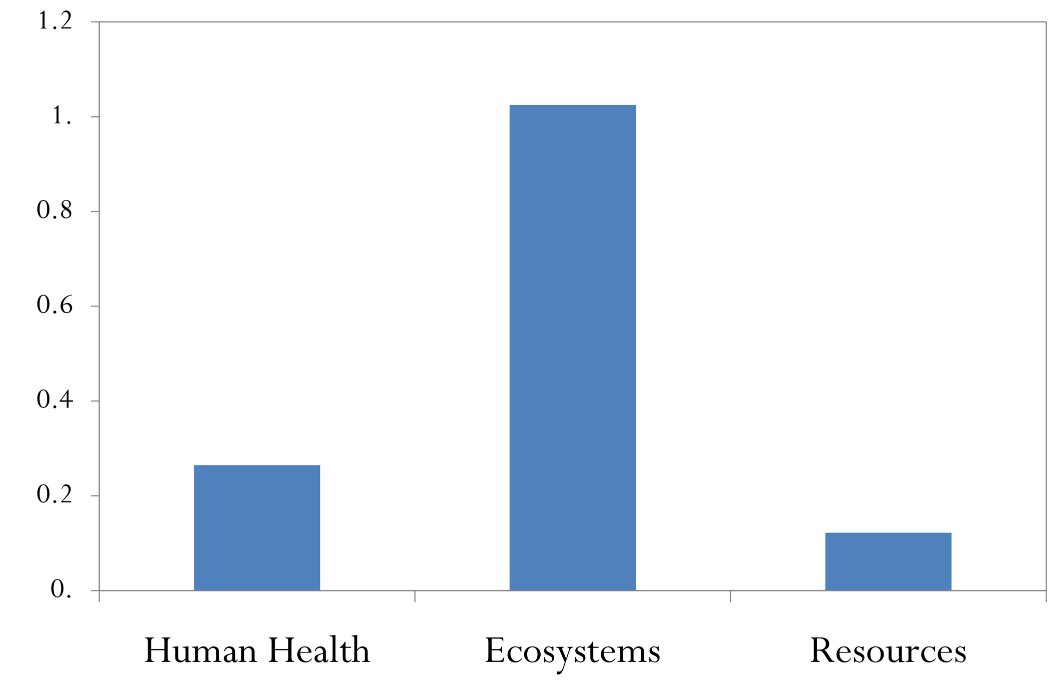
(1) The modulation of chemical inputs can greatly affect the environmental implications of a systems entire life cycle.
(2) The agricultural phase of biodiesel is detrimental to the ecosystem through its assumed uses of fertilizers.
(3) Unit processes of a system are extremely difficult to accurately replicate.

Through the studying of LCA, one of the greatest lessons that may be gleaned is that LCA is not an absolute indicator of impact. It is of the upmost importance that the practitioner "do[es] not indicate that actual impacts will be observed in the environment because of the life cycle of the product or process under study, but only that there is a potential linkage between the product or process life cycle and the impacts" ((Heijungs, R. and Guinée, J.,1993). This is not to say LCA is by *de facto* an outmoded practice but rather that it remains provisional.

Although not explicitly discovered from the scope of the project, important to the discourse in regards to the LCA of biodiesel are two ideas:

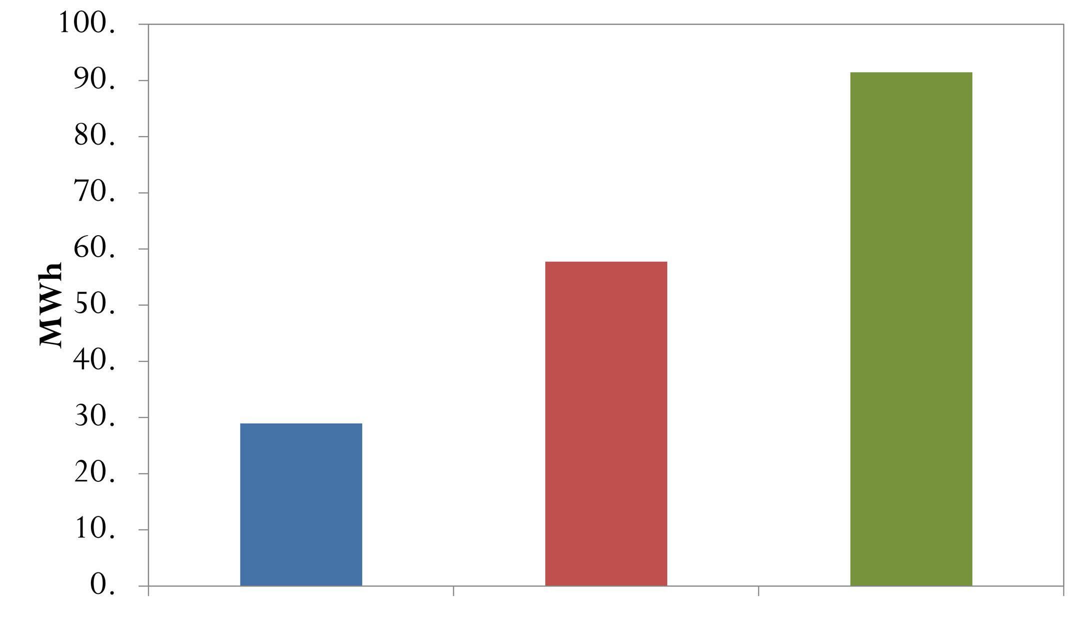
(1) The highest energy consumption of the biodiesel life cycle comes from the transesterification process which may be attributed to the use high use of electricity and heat (Ahmed, Irshad, John Decker, and David Morris, 1994).
(2) Biodiesel remains to have less CO_2 and SO_x emissions upon combustion, however, No_x are slightly higher (De Nocker L., Spirinckx C., Torfs R., 1998).

Results



Graph 1. ReCiPe Endpoint normalization of 1000kg of soybean based feedstock

- The raw material phase (i.e. agricultural production of feedstock crop) impacts the environment through the usage of fertilizers.



Graph 2. CED of the modulation of MeOH and NaOH feeds used within the transesterification process

- Yield rates, molar ratios, and percent recovery of materials are important to the environmental impacts and energy usage of the transesterification process.

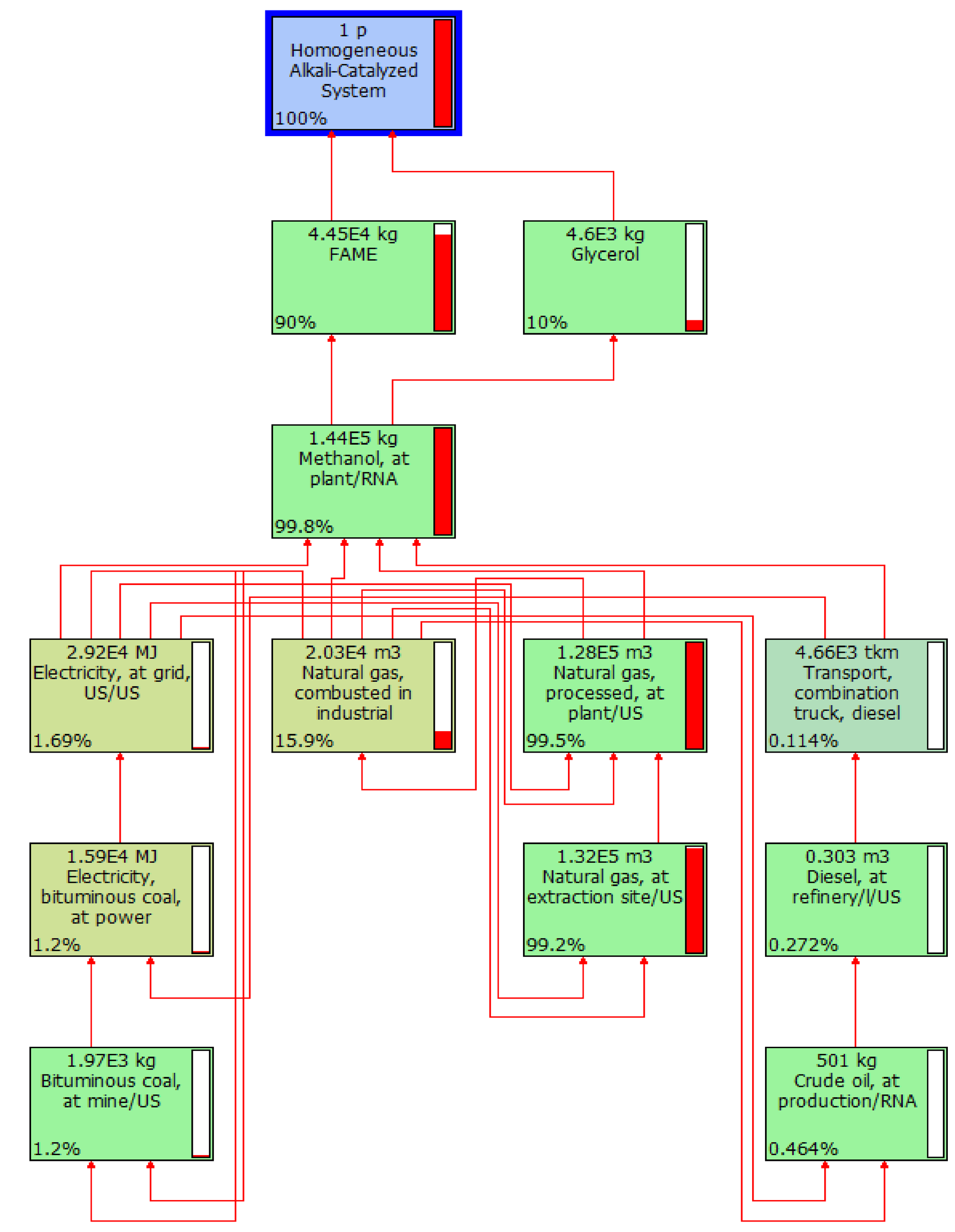


Figure 3. Network diagram of unit processes of transesterification

- There multiple unit processes that make up a system. Each unit process has data that is associated to particular impact categories.

Future Work

- Further expand the existing model of the pre-treated homogeneous alkali catalyzed system.
- Conduct further work on the 3rd system boundary
- Gain greater understanding of the in-depth analysis and awareness required to publish and complete comprehensive LCAs.
- Develop screencasts with simple projects within the SimaPro software to allow ease of use for first time users.
- Create new models that represent a heterogeneous acid-catalyzed system, supercritical process, and a baseline petrodiesel
- Use other LCA software—more specifically, GREET 2013—to create similar models of biodiesel life cycles.
- Solve the energy crisis!

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