University of South Florida

Feasibility, Sustainability and Economic Analysis of Solar Assisted Biomass Conversion

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Description: The main deterrent for commercialization of biomass conversion processes is the cost of conversion; particularly the need to sacrifice as much as 30% of the energy content in the biomass for the thermo chemical conversion step. We want to research and develop the concept to use solar thermal energy from concentrating units to provide energy for the biomass gasification step. We also propose to evaluate the sustainability of such a process.

Overall Objective: The overall objective is to conduct a theoretical analysis of solar assisted thermo chemical conversion of biomass from the point of view of energy efficiency, economic feasibility, environmental impact, and long term sustainability of renewable energy production.

Budget: $45,238
Universities: USF

Funds leveraged or new partnerships created.
Partnerships were created with faculty in the Civil and Environmental Engineering and faculty at UF to submit a NSF EFRI proposal on Sustainable Microalgae Bioenergy Systems.
Partnerships were created with UF (College of Agriculture), NREL, ORNL, and US Forest Service to submit a proposal to the BRDI (Biomass Research and Development Initiative) program run jointly by DOE and DOA.

Progress Summary

Overall Objective: The overall objective is to conduct a theoretical analysis of thermo chemical conversion of biomass with and without solar energy from the point of view of energy efficiency, economic feasibility, environmental impact, and long term sustainability of renewable energy production.
We completed process design and economic analysis of the thermochemical conversion of biomass to liquids with and without solar energy. The results are included in the 2012 Annual Report below. It was found that the capital cost of the solar energy collection system is a significant factor in the economics of the process. The cost of solar thermal systems will have to be significantly reduced before solar assisted biomass gasification can become feasible.

Based on economic analysis, the goal of LCA has been shifted to compare different feedstocks and processes because solar assisted biomass conversion is not economically feasible. In this study, a comparative LCA has been developed to evaluate the environmental impacts associated with different energy products via different routes across the whole life of algal and lignocellulosic bioenergy. Results were compared per energy basis, the production of 1 million BTU of energy products. It was found that cultivated algae biomass feedstock has much higher environmental impacts compared with lignocellulosic biomass feedstock from forestation and agriculture byproducts. It was also concluded that thermochemical gasification and FTS process showed higher efficiency when converting biomass to bioenergy.

2012 Annual Report

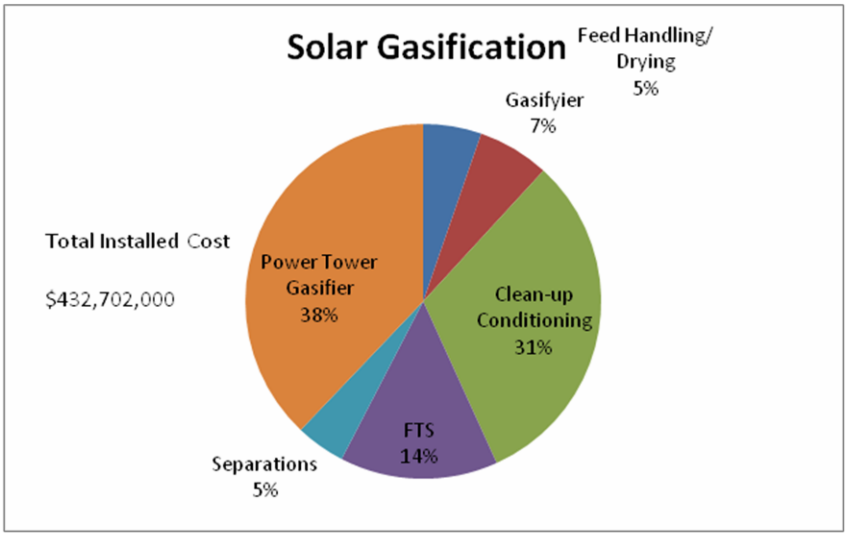
The objective for this FESC project was to conduct a theoretical analysis of solar assisted thermochemical conversion of biomass from the point of view of energy efficiency, economic feasibility, environmental impact, and long term sustainability of renewable energy production. The specific objectives for our group are to evaluate the design, economic feasibility and environmental impacts and long term sustainability of solar assisted biomass conversion and identify the opportunities for technological improvement.

To achieve the above objectives, two different systems will be compared: (1) biomass conversion without solar unit and (2) solar assisted biomass conversion. The first case is based on an NREL study which looked at the feasibility of producing mixed alcohols from biomass. NREL report outlines the general process design and economics for this process. This process was modified to produce hydrocarbon fuels by changing the catalyst used in the Fischer-Tropsch Synthesis step.

In the second case we decided to investigate the economic feasibility of a "power tower" gasification approach in which a gasifier would be housed in the central receiver of a 150 meter tall tower that would be directly heated by heliostats (mirrors) to reach temperatures in excess of 1800F. The tower would have roughly 500-600 acres of heliostats associated with it to provide the energy needed for gasification. The heliostats would focus the suns energy to the top of the tower which will then heat the gasifiers to 1800F. The capital investments for the solar technologies in this case were estimated at $120 million. This adds significantly to the overall cost of the biomass liquefaction system.

This type of gasification will require much R&D to be successful. The technology for central receiving solar power tower heat generation is not new, and is a proven, but not yet fully embraced, as a way of producing electricity. The strategic placement of the mirrors around the tower can create very serious logistical problems in regards to land usage within the plant, and should be worked out carefully. The main goal in the design of the central receiver is to provide the thermal fluxes needed for indirect steam gasification.

A process design using the NREL report as a basis was completed and the results indicate that the solar assisted conversion costs significantly more based on the current estimates of the costs of solar concentrating units. As the costs of the parabolic troughs used for solar energy conversion is reduced (mass production will lower costs) the use of solar energy to assist the gasification step will become more economical. The following figure shows the capital cost breakdown for a solar assisted plant.



Life Cycle Analysis

Based on the above economic analysis, the goal of LCA has been shifted to compare different feedstocks and processes because solar assisted biomass conversion is not economically feasible. Lignocellulosic and algae biomass have been evaluated as promising feedstocks for bioenergy production. In this study, a comparative LCA has been developed to evaluate the environmental impacts associated with different energy products via different routes across the whole life of algal and lignocellulosic bioenergy. Results were compared per energy basis, the production of 1 million BTU of energy products.

For the development of the comparative algae biomass conversion LCA, algal biomass was converted to liquid biofuels via a thermochemical gasification and Fischer-Tropsch Synthesis (FTS) process; and to electricity and heat via anaerobic digestion and combined heat and power (CHP) process. Results from the algae biomass conversion LCA (Figure 2) showed that the process that converts algae biomass through anaerobic digestion and CHP process to electricity and heat had the highest overall environmental impact. Results also showed that the impact categories that appear to contribute the most to the overall impacts are ecotoxicity, human health non-cancer, and human health cancer.

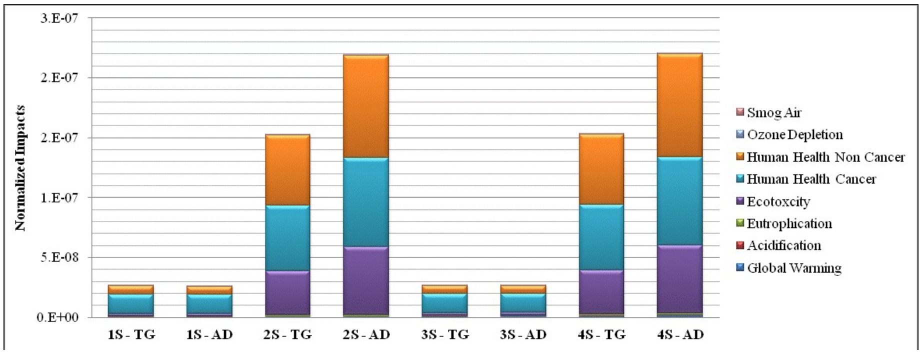


Figure 2. Results from the comparative algae biomass conversion LCA. (TG: thermochemical gasification; and AD: anaerobic digestion; 1S: Wastewater is used as a source of nutrients and flue gas is used as a source of CO_2, assuming the process is co-located with a power plant; 2S: Fertilizers are used as a source of nutrients, and Flue Gas is used as a source of CO_2; 3S: Wastewater is used as a source of nutrients, and chemical CO_2 is used as the carbon source; 4S: Fertilizers are used as a source of nutrients, and chemical CO_2 is used as the carbon source.)

For the development of the comparative lignocellulosic biomass conversion LCA, lignocellulosic biomass was converted to ethanol and higher alcohols through thermochemical gasification and alcohol synthesis process (process 1), to liquid biofuels via thermochemical gasification and FTS process (process 2), and to liquid biofuels via a thermochemical gasification and FTS process that uses methane (process 3). Results from the lignocellulosic biomass conversion LCA (Figure 3) showed that the process that converts lignocellulosic biomass into alcohols has the highest overall environmental impact. Results also showed that the impact categories that appear to contribute the most to the overall impacts are ecotoxicity, human health non-cancer, human health cancer, and global warming.

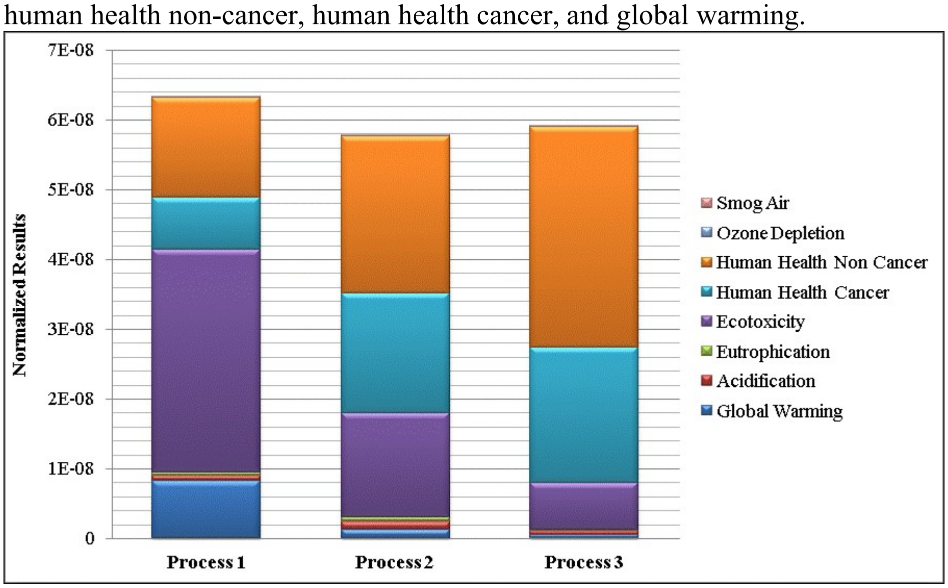


Figure 3. Results from the comparative lignocellulosic biomass conversion LCA.

This study determined that cultivated algae biomass feedstock has much higher environmental impacts compared with lignocellulosic biomass feedstock from forestation and agriculture byproducts as shown in Figure 4. It was also concluded that thermochemical gasification and FTS process showed higher efficiency when converting biomass to bioenergy (see Figures 5 and 6).

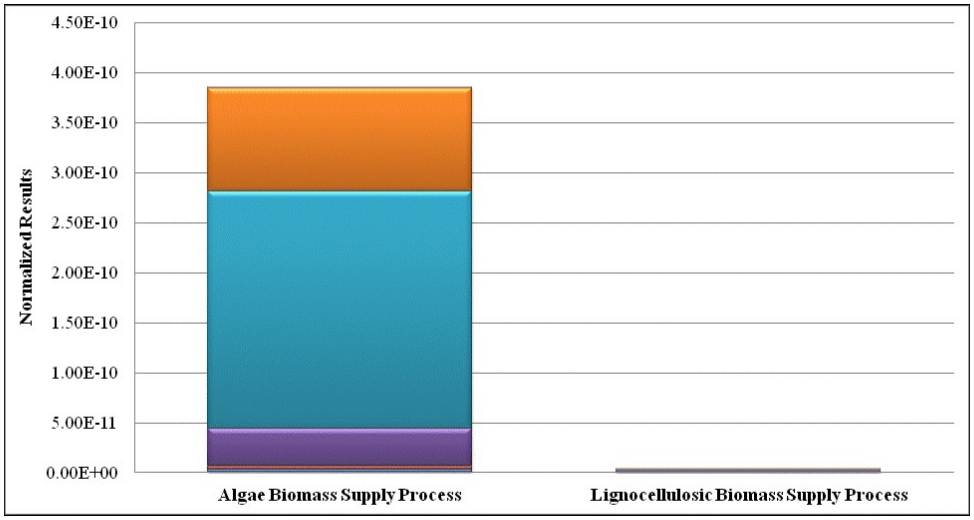


Figure 4. Results for comparative analysis on feedstock type

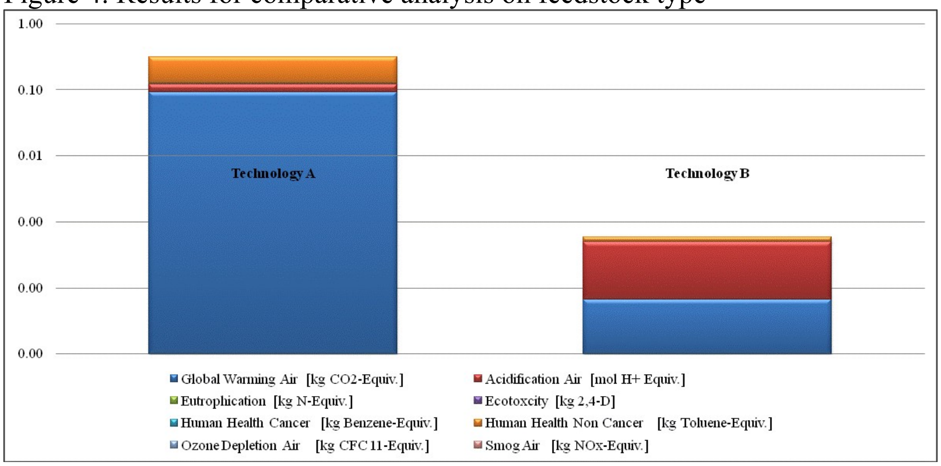


Figure 5. Comparison of algae biomass conversion technologies when producing 1 BTU algae biomass-derived energy. (Technology A: anaerobic digestion and combined heat and power (CHP) process; Technology B: thermochemical gasification and Fischer-Tropsch Synthesis)

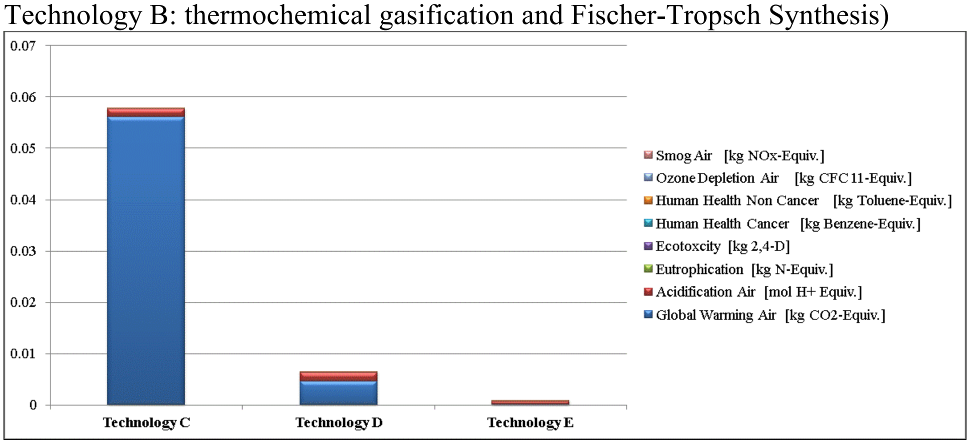


Figure 6. Comparison of lignocellulosic biomass conversion technologies when producing 1 BTU algae biomass-derived energy. (Technology C: thermochemical gasification and alcohol synthesis process; Technology D: thermochemical gasification and FTS process; Technology E: thermochemical gasification and FTS process that uses methane)

Publications, presentations, patents, licenses, industry interactions, etc.

- Pinilla, M., Q. Zhang, and B. Joseph, Comparative life cycle assessment (LCA) of lignocellulosic biomass conversion into different energy products, 2011 FESC Summit, Gainesville, FL, Sept 27-28, 2011. (oral presentation)
- Pinilla, M., Q. Zhang, and B. Joseph, Comparative life cycle assessment (LCA) of biofuels and electricity production from algal biomass, 2011 FESC Summit, Gainesville, FL, Sept 27-28, 2011. (poster presentation)
- Obregón, M. J. P., B. Joseph, and Q. Zhang, Life Cycle Assessment of Algae Biomass Conversion to Various Energy Products through Different Pathways. In preparation
- Obregón, M. J. P., B. Joseph, and Q. Zhang, Comparative Life Cycle Assessment of Lignocellulosic Biomass Conversion to Various Energy Products through Different Pathways. In preparation
- *Matt Wetherington and Babu Joseph* . Cost Models for a Biomass Based Transportation Fuels Plant. Florida Energy Systems Consortium Annual Summit. University of Central Florida, Orlando, Sept 2010.
- Syed Ali Gardezi, Babu Joseph, and John T. Wolan, Fischer Tropsch Synthesis Via Biomass Derived Synthesis Gas, Paper 231c, AIChE Annual Meeting, Minneapolis, MN, Oct 2011.
- Syed Ali Zeeshan Gardezi, John T Wolan, Babu Joseph., An Integrated Approach to the preparation of effective Catalysts for Biomass-to-Liquid (BTL) processes, AIChE Central Florida International Conference, Clearwater, FL, June, 2012