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CHE418- Chemical Engineering Design III
Rose-Hulman Institute of Technology
Dr. Ron Artigue
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May 5, 2015

Dr. Artigue:
Since fossil fuel reserves are being depleted, companies are trying to come up with ways to produce fuel from other sources, such as sludge. Powerdyne is one of these companies. This project analysis was done for Powedyne and Terre Haute's knowledge. It looks into the possibility of producing biodiesel fuel using sludge produced by the Terre Haute Wastewater Treatment Plant. During our project we were required to model the process and supply documentation supporting whether or not this process is feasible. The primary objectives of the project were to determine the technical and economic feasibility of producing 12 million gallons of biofuel a year (MGY) from sludge.
The project analysis took place from March 9, 2015 to May 4, 2015. We spent the first two weeks researching how to produce biofuel, how much sludge would be required to produce 12 MGY, and what equipment would be needed. The next four weeks we worked on equipment and process design for the facility. Finally, the last two weeks were spent performing a cost analysis on the process.
The design process that was developed in order to produce the biofuel consists of a plasma gasifier and Fischer-Tropsch reactors. Powerdyne specified that this equipment was to be used in the process. They also specified that the fuel would be sold for a contract price of $2.46 per gallon for 20 years. When designing this process we determined that 305,000 ton/yr of sludge are needed to produce 12 MGY of biodiesel. Also, as part of the cost analysis it was determined that the process has a Net Profit Value (NPV) of -$1.9 billion.

Sincerely,

Anna Taylor

Anna Taylor
Primary Editor

Powerdyne: Biofuel from Sludge Process

May 5, 2015
Group 11, Chemical Engineering Design III
James Files, Sam Jordan, Sam Peters, and Anna Taylor
Submitted to: Dr. Ronald Artigue

Summary

The objective of this report is to analyze the technological and economic feasibility of the Powerdyne diesel process, which uses sludge as the feedstock to produce 12 million gallons of diesel fuel per year. This process is to take the wastewater sludge produced by the Terre Haute Wastewater plant, use it as the feedstock for conversion to syngas, and then convert the syngas into a mixture of hydrocarbons, some of which would be the diesel product. Key design elements considered were the feasibility of the process, the sizing of the equipment, and the utility requirements. The process was found to be technologically feasible; however, it would require a significantly large volume or large number of equipment units (18 dryers required with a heat transfer area of 3,025 ft2). The utilities required include electricity, cooling water, steam, natural gas, and Paratherm heating fluid. The economic aspects considered include the profit and loss statement which includes an overall gross profit, the rigorous profitability analysis with a net profit value (NPV), and several cost sensitivity analyses. The overall gross profit obtained was -$266.8 million and the NPV was -$1.9 billion. In order to break even on the gross profit, the diesel product would have to be sold at $26.44 per gallon. Overall, technologically, the diesel process could be feasible; however, at current prices, the process would result in a large economic loss.

Project Scope

Powerdyne is looking to establish a biofuel production facility in Terre Haute, Indiana using sludge from the Terre Haute Wastewater Treatment Plant [1]. This design project examines the technical and economic feasibility of the production process. It takes into account the equipment and materials, the amount of heat and power, and the number of employees required for the production of biofuel, along with the cost of the process. It also looks at environmental and safety concerns associated with the process and materials used.

The production facility would be located at 1445 First Street in Terre Haute, IN on approximately 75.8 acres of land. The majority of the land would be consumed by the processing equipment. The major pieces of equipment are 18 dryers, 1 plasma gasifier, 3 shift reactors, 1 hydrogen sulfide and carbon dioxide scrubber, 10 Fischer-Tropsch (FT) reactors, an atmospheric distillation column, and an alkylation unit. The sludge would be brought in by truck and unloaded directly into the dryers. The minimal amount of waste produced will be within the limits set by the Environmental Protection Agency (EPA) [2]. All products and by-products will be sold for profit and will be transported by truck.

Powerdyne specified that the plant be capable of producing 12 million gallons of biofuel per year (MGY). Also, the 20 year contract that Powerdyne has proposed states that the biodiesel will be sold for $2.46 per gallon [1]. It was assumed that any sludge feedstock coming from the Terre Haute Wastewater Treatment Plant is free of charge and any sludge feedstock from any other waste water treatment plant has a cost solely of transportation. The amount of sludge feedstock needed for this process is approximately 305,000 tons/yr (610 million lb/yr), which is 19 times the amount of sludge

that the Terre Haute Wastewater Treatment Plant produces, thus sludge from other wastewater treatment plants would be required[3].
In order to reduce the costs of utilities the process will use the steam effluent of the dryers to heat the distillation column and the alkylation unit. The amount of steam given off by the dryer is 1,415 million lb/yr, while the distillation column needs 106 million lb/yr and the alkylation unit needs 15.6 million lb/yr of steam. The process will be laid out in one main processing line.
Some other major assumptions made in this report are that the plant will operate 24 hours a day for 365 days a year. When the process was modeled in Aspen Plus v.8.2 the REQUIL model was used for the shift reactor and RGIBBS was used for gasifier and FT reactor. Also, the 7

units of measurement for this report are in English units, with M in all units meaning 106, and other common units being million gallons per year (MGY), million cubic feet per year (Mft3/yr) million pounds per year (Mlb/yr), and million tons per year (Mtons/yr).

May 15, 2015

Dr. Ron Artigue,
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Dr. Artigue,

The following report details a design for a plant that makes diesel from human wastewater sludge. Powerdyne, a company that supposedly produces renewable fuels, has proposed a plan to the city of Terre Haute to construct this type of plant. The purpose of this project was to determine if such a plant would be feasible and/or economically viable. After extensive research, we have concluded that a plant such as this is not feasible or economically viable. Powerdyne has claimed that they can produce 12 million gallons of diesel fuel a year. In order to reach this number, the plant would require 40,000 tons per day of wet sludge, which far exceeds the amount of sludge Terre Haute produces every day. The economic outlook of the plant is just as bad. Selling the diesel for $2.46/gallon, as was claimed by Powerdyne, results in a $36 million gross loss. The NPV after 20 years is negative $271 million. In order to just break even after 20 years, the plant would need to sell the diesel for $9.35/gallon, nearly four times the amount claimed by Powerdyne.

For the reasons stated above, the group would strongly recommend the city of Terre Haute not to go through with the construction of this plant. This could end up costing the city, which is already under financial duress, millions of dollars. Refineries already in existence that convert fossil fuels to liquids are a much better investment.

Sincerely,

Alexander Clayton, Emily Davis, Matthew Palla, Andrew Strebing

Biodiesel from Wastewater Sludge via Plasma Gasification and Fischer-Tropsch Synthesis

Spring 2015

Alexander Clayton, Emily Davis, Matthew Palla and Andrew Strebing

Executive Summary

The objectives of this project are to design a system that will allow sewage sludge to be converted to diesel and determine the feasibility of this process. According to a company called Powerdyne, 12 million gallons of diesel fuel can be produced per year in such a plant given the amount of sewage sludge that is produced by Terre Haute. The company claims that the production of this diesel would bring in $480,000 annually, under the condition that the city signs a 20 year contract indicating that Terre Haute would purchase the diesel from Powerdyne for $2.46 per gallon and sell it to a third party company for $2.50 per gallon [1].

Using a basis of 12 million gallons of diesel produced per year, it was determined that the plant would require 45,464 tons of sewage sludge containing 97 wt% water per day. Dewatering the sludge was outside the scope of the project, so it was assumed that the required amount of sludge enters the process in the form of pellets with a moisture content of 20 wt%. For the process, plasma gasifiers are used to incinerate the sewage sludge in order to form syngas. The syngas is then cooled using a radiant syngas cooler, and the carbon monoxide and water in the syngas is converted to hydrogen and carbon dioxide in a high-temperature water-gas shift reactor. After this, the syngas is cleaned by an acid gas removal system. The clean syngas enters a Fischer-Tropsch reactor where it is converted to wax and lighter hydrocarbons. Using a flash vessel and distillation column, the hydrocarbons are separated. More wax is separated in bottoms from the distillation column, and it combines with the wax exiting the Fischer-Tropsch reactor.

The wax enters a hydrocracker where it is broken into lighter hydrocarbons, which are recycled back to the feed of the distillation column.

The equipment utilized for this process are fairly expensive, resulting in a total capital investment, C_{TCI}, of approximately $300 million. This value was determined using the Overall Factor Method of Lang. Additionally, the total production cost of this plant is $87 million, which is primarily due to the process's utility requirements and maintenance costs. As a result, even considering the credit from biodiesel RINs, the gross loss is nearly $36 million each year. Assuming a ten year MACRS depreciation and an income tax rate of 40%, after 20 years the calculated NPV of this plant is negative $271 million. This indicates that this plant will never generate enough income within the 20 year contract.

Because the NPV remains negative even after 20 years, it is not recommended that this project be cared out. In order to breakeven on initial investment, the diesel would have to be sold for $9.35 per gallon. This value is nearly four times the greater than the price Terre Haute could sell the diesel for as stated in the contract. As a result, significantly more testing and research should be done before Terre Haute should consider such a plant.

Project Scope and Limitations

Project Premises:

The objective of this project is to evaluate the technological and economic feasibility of a commercial-scale biomass to liquids (BTL) plant. A BTL plant located in Terre Haute, Indiana in which municipal wastewater sludge is converted to biodiesel is the focus of this project. Powerdyne, the company wanting to build this plant, is claiming to be able to produce 91 tons per day of biodiesel product for $2.46 per gallon. This diesel product will then be sold to a third party for $2.50 per gallon and Terre Haute will profit off the price margin. Regardless of how

expensive the diesel is to make, Terre Haute must supply a third party the required amount of diesel at $2.50 per gallon [1].

The scope of the project does not include the transportation of the wastewater sludge to the plant. The project also excludes the initial steps of drying and centrifuging the wastewater sludge as well as the specific separations and refining steps at the back-end of production. Therefore, the feedstock of carbonaceous material is assumed to be dried sludge pellets with a moisture content of 20 wt%. These pellets are assumed to be available free of cost at the plant location.

The feed sludge material is assumed to have a carbon content of 32% on a dry weight basis [2]. The syngas composition leaving the gasifier is assumed to be similar to the composition found in the AlterNRG material balance [3]. Although the AlterNRG material balance is based on municipal solid waste (MSW), it is used as a best estimate, and the syngas compositions are adjusted based on a carbon balance around the plasma gasifier. In the acid gas removal system, it is assumed that all carbon dioxide, hydrochloric acid, hydrogen sulfide, carbonyl sulfide, ammonia, and hydrogen cyanide is removed. The water gas shift reactor is modeled in Aspen where the only reactions present are the water shift reactions. A hydrocarbon distribution for the Fischer-Tropsch product was found and optimized to maximize diesel production. Once again the carbon balance is assumed to be most important and is used to consolidate the Fisher-Tropsch outlet with the water gas shift outlet. Perfect separation is assumed in the distillation column. The basis of Powerdyne's 91 tons per day of diesel product is used to calculate the flowrates and unit sizes.

Market Research: As early as May of 2014, the Board of Public Works and Safety has begun approving contracts with the private company Powerdyne. The contracts allow Powerdyne

to convert the sewage sludge produced by Terre Haute into diesel in an environmentally friendly, zero-emission manner [4]. Powerdye will then sell the diesel to Terre Haute for $2.46 per gallon. From there, Terre Haute will sell the diesel to a company called Sodrel Fuels for $2.50 per gallon [5].

This deal appeals to Terre Haute because of its potential to bring money into the city. Because the city has been struggling financially since the recession, Mayor Duke Bennett has spent the last couple of years trying to find ways of generating new revenue. According to Powerdyne, the deal would create $480,000 per year for Terre Haute. However, the city's director of waste water utility Mark Thompson believes that the city can produce more sludge than contracted, therefore increasing the amount of money the city is paid by the deal [5]. Additionally, the deal would create 1,000 jobs while the plant is being built over a period of two years. Then, the plant would employ 100 to 130 people, which would help to boost the economy of Terre Haute [4].

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