OPTIMAL ALTERNATIVE FOR INTEGRATING SOLAR ENERGY AND WATER TREATMENT SYSTEM IN THE BIODIESEL PRODUCTION

Capstone Design

EGR 4402

Spring 2019

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Spring 2019
OPTIMAL ALTERNATIVE FOR INTEGRATING SOLAR ENERGY AND WATER TREATMENT SYSTEM IN THE BIODIESEL PRODUCTION

Capstone Report

Student Statement:

“I, Israe Rouri, have applied ethics to the design process and in selection of the final proposed design. I have held the safety to the public to be paramount and have addressed this in the presented design wherever may be applicable.”

Israe Rouri

Approved by the Supervisor(s)

Dr. El Asli Abdelghani
ACKNOWLEDGEMENTS

First of all, I would like to thank my supervisor Dr. Abdelghani El Asli for his continuous support throughout this whole semester, Mr. Mohamed Jadid for taking the time to help me in this project, and Professor Rachid Lghoul for providing me and helping me with the RETSCREEN software. In addition, I would also like to thank my family for their support throughout my journey in AUI. Last but not least, my friends and roommates Inès Benomar and Hind Belgued for being a great emotional support during this semester.
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ABSTRACT

The main goal of this capstone project was to look for an optimal choice concerning the type of energy used for the pre-treatment and treatment phases of the biodiesel production, then looking for the optimal water treatment system for the post-treatment phase. This work was divided into two parts; the first one comprised of a discussion all the methods used for each phase, and a comparison between the thermal and PV, as well as another comparison of the methods used for the water treatment. In the second part, I included an-in-depth description of the process of producing biodiesel. Finally, I concluded this work by a discussion of the reason behind my choice of using thermal energy as a heating source for the pre-treatment and treatment, then the choice of coagulation/flocculation for the wastewater treatment of the biodiesel.
ABSTRACT

Ce projet a pour but de rechercher un choix optimal concernant le type d’énergie utilisé pour les phases de prétraitement et de traitement de la production de biodiesel, puis à rechercher le système de traitement d’eau optimal pour la phase de post-traitement. Ce projet est divisé en deux parties ; la première discute toutes les méthodes utilisées pour chaque phase et fait une comparaison entre l’énergie thermique et l’énergie solaire photovoltaïque et une comparaison des méthodes utilisées pour le traitement de l'eau. Dans la deuxième partie, j’ai décrit en détails le projet qui concerne le processus de production de biodiesel. J’ai conclu ce rapport par la raison de mon choix pour l’énergie thermique en tant que source de chaleur pour le prétraitement et le traitement, puis pour le choix de la coagulation/floculation pour le traitement des eaux usées du biodiesel.
1 INTRODUCTION

1.1 Social Context and Motivation

Generating sustainable energies at an acceptable price without causing any damage to the human nourishment is as difficult as the decrease of greenhouse gases provoked by petroleum products. In Morocco, researchers and scientists are working in providing petroleum reserves. Different plants devoted to power generation utilizing wind and solar energy are performed, or still in process. “Green Morocco” created by the Moroccan government has for principal motivation to develop industrial agriculture, comprising oilseed plants.

1.2 Methodology and Objectives

This capstone report is divided into three main parts; first one is devoted to literature review as a way to summarize all the papers read and research done for this capstone project. These papers discussing the multiple methods used in all the stages. Then, comparing thermal and PV energy, and the water treatment methods. In the third part, I will be discussing different aspects of this capstone using the STEEPLE analysis. The last part is about the project description and the optimal choice for the type of solar energy and wastewater treatment method.
As the world’s population is growing, the need for substantial energy resources is expanding. Fossil fuel are massively used in the production of energy to generate electricity that is needed in our today’s world.

Renewable energy is becoming more popular as fossil fuels reserves are depreciating. To limit our impact on earth, investment and interest are put towards generating clean energy. As scientist developed alternative resources that produce comparable efficient energy that limits the CO2 emissions. [1] Many kinds of renewable energies are available, but their extraction and treatment involve a considerable investment, although the payback period for the investment is attractive in comparison to fossil fuel. Countries in the world are therefore more appealed to renewable energies to compensate the need of the population.

In the US, from 2000 to 2017, the production and consumption of renewable energy have increased and will continue so according to the US Energy information administration. [1] Countries from all around the world are encouraging the production of renewable energy as well as research and projects in the field.
3 LITERATURE REVIEW

3.1 First Generation

The first-generation biofuel involves materials extracted from sugar, vegetable oil, animal fat as a way to produce heat. The oil obtained from these materials goes through different type of process. Different types of first-generation biofuels are:

- **Biodiesel**: this type is the most widely recognized kind of biofuel, generally used in the European nations. This kind of biofuel is primarily produced through a procedure called transesterification. This process comprises the reaction of glyceride with alcohol with the attribution of a catalyst creating “fatty acid alkyl esters and an alcohol.” [2] In other words, this process comprises combining the biomass with alcohol (either methanol or ethanol) with sodium hydroxide, which lead to the production of biodiesel. This type of biofuel is mainly used for different diesel motors after infusing it with mineral diesel. [2] Nowadays, in multiple countries the makers of the diesel motor guarantee that the engine functions well with the biodiesel.

- **Vegetable oil**: These types of oil can be either utilized for cooking reason or even as fuel. The main factor that determines the utilization of this oil is the quality. If the oil has good quality, it is used for cooking reason. [2] In addition, vegetable oil can even be utilized in the majority of the old diesel motors, but only in warm climate. The majority of countries use vegetable oil to produce biodiesel.

- **Biogas**: Its it principally created after the anaerobic assimilation of the natural materials. Biogas can likewise be created with the biodegradation of “waste materials which are fed into anaerobic digestion which yields biogas.” [2] The remainder can be effectively utilized as compost or manures for agricultural purpose. The biogas created is very wealthy in methane which can be effectively recuperated using mechanical biological
treatment frameworks. Another type of biogas is the landfill gas which is made through the use of happening anaerobic digesters, however the main danger is that these gases can be a serious risk if escapes into the air.

- **Bio-alcohols:** They are alcohols created by the utilization if enzymes and micro-organisms through the procedure of fermentation of stachers and sugar. Ethanol is the most widely recognized kind of bio-alcohol though butanol and propanol are a portion of the lesser known ones. Biobutanol can also be considered as a direct substitution of gasoline because it can be used in different gasoline motors. Butanol is produced through ABE fermentation (using carbohydrates to produce acetone-butanol-ethanol). [2] In addition, some experiments have shown that butanol is considered to be an energy efficient fuel to be used in the different gasoline engines.

- **Syngas:** It is produced after the mixed process of gasification, combustion, and pyrolysis. Biofuel used in this procedure is changed over into carbon monoxide and after that into energy by pyrolysis. During this procedure, a small amount of oxygen is provided to monitor the burning phase. In the last stage (gasification), the organic materials are changed over into gases like carbon monoxide and hydrogen. [2] The subsequent gas Syngas can be utilized for different reasons such as producing automotive and transportation fuels.

### 3.2 Second Generation

The difference between first and second generation is this one doesn’t use food crops as feedstock to produce biofuels. However, food crops can be considered as a second-generation biofuel if they effectively satisfy their food purpose. For example, used vegetable oil is considered to be a second-generation biofuel because it has already been used and it is no longer
good for the human body. [3] However, virgin vegetable oil is considered to be a first-generation biofuel because it still hasn’t been used anywhere.

On the other hand, a different type of technology is used to derive energy from them. However, this doesn’t imply that second generation biofuel can’t be scorched explicitly as the biomass. Indeed, multiple second-generation biofuels are developed purposely to act as biomass.

3.2.1 Extraction Technology

Generally, second generation feedstock are made in a different way than the first-generation biofuel. This is especially valid for lignocellulose feedstock, which will in generation require a few preparing steps before being fermented (a first-generation innovation) into ethanol. [3]

3.2.2 Thermochemical Conversion

“The first thermochemical route is gasification”. [3] Second generation gasification advancement is a technology that has been used broadly on ordinary fossil fuels for many years. Second generation gasification advancements have been somewhat modified to accustomate the distinctions in biomass stock. Through gasification, carbon-based materials are changed over to carbon monoxide, hydrogen, and carbon dioxide. [3] This procedure is not quite the same as combustion in that oxygen is restricted. The resultant gas is referred to as union gas of syngas. Syngas is then used as an energy or heat source. In this process, feedstock such as wood, brown liquor, and black liquor are used.

The second thermochemical route is pyrolysis. Pyrolysis is carried out while there is no sign of oxygen presence and regularly within the sight of halogen (inert gas). The fuel is commonly changed over into two products: tars and char. To get bio-oil through pyrolysis, wood and various other energy crops can be utilized as feedstock. [3]
The third thermochemical reaction, torrefaction, it is similar to pyrolysis, but this one is done at lower temperatures. The procedure will generally yield better fuels for more utilization in gasification or combustion. [3] Torrefaction is regularly used to change over biomass feedstock into a form that is more effectively transported and stored. [3]

3.2.3 Biochemical Conversion

For the production of biofuel from second generation feedstock, various biological and chemical processes are being done. One process that is known to be used in the second-generation feedstock is fermentation. [3]

To qualify as a second era feedstock, a source must not be appropriate for human utilization. It's anything but a prerequisite that the feedstock be developed on non-farming area, yet it by and large abandons saying that a second era feedstock ought to develop on what is known as minor land. Negligible land will be land that can't be utilized for "arable" crops, which means it can't be utilized to viably develop nourishment. [3] The implicit point here is that second era feedstock ought not require a lot of water or manure to grow, a reality that has prompted frustration in a few second era crops.

3.3 Third Generation

The term third generation biofuel is any biofuel extracted from algae. Beforehand, “algae were lumped in with second generation biofuels. [4] However, algae are able to produce more higher yields with lower asset contributions than other feedstock, many recommended that they be moved to their own classification. As we will illustrate, algae have a number of advantages.
**Fuel Potential**

Concerning the possibility to get fuel, no feedstock can have the same quantity or diversity of algae. The decent variety of fuel that algae can deliver results from two attributes of the microorganism. In the first place, algae produce an oil that can without much of a stretch be refined into diesel or even some segments of gasoline. [4]

Butanol is an interesting alcohol because it is particularly like gasoline. Indeed, it has an almost similarity energy density to gasoline and an improved diffusion profile. Until the approach of genetically adjusted algae, scientists faced difficulties to deliver butanol. [4] Presently, multiple commercial-scale tools have been adjusted to make butanol. Here is a list of the fuels that can be extracted from algae:

- Biodiesel
- Butanol
- Methane
- Vegetable Oil
- Gasoline
- Jet Fuel
- Ethanol

### 3.4 Why Biodiesel?

Morocco is struggling to accommodate its expanding population’s energetic requirements. Fossil fuel is the most dominant source of energy for Morocco. The lack for substitutes impacts the country’s economy and as a result it’s political stability. As Morocco has low fossil fuels supplies, the country struggles to meets its population demand. As a result, researchers and scientists have been exploring whether biodiesel is a convenient solution.
Biodiesel will also contribute in reducing the amount CO2 emissions which are considerably polluting the air and affecting people’s health. [5]

Biodiesel is one of the most relevant alternatives to diesel fuel. It is environmentally friendly, safe and sustainable and can easily be produced through the transesterification of oils; vegetable, animal fats and used cooking oils. [5]

Vegetable oils are essential resources for food consumption and therefore the process is impractical and costly. Other oils can be used as better substitutes including brown greases and waste cooking oil. These substances contain a high quantity of free fatty acid which must be reduced and converted to biodiesel. Pretreatment has become crucial in preparing the feedstock to produce biodiesel. Biological delignification is an appealing approach for pretreatment of lignocellulosic biomass. This approach is effective and cost saving. It also appears to be ecological and safe and requires a relatively low amount of energy.

3.5 Thermal vs PV

They’re two sorts of direct solar energy innovation: solar thermal and solar photovoltaic (PV). These technologies have the same purpose which is to collect the sun rays that attain the atmosphere and convert them to energy. However, both have different ways to obtain the sun rays.

3.5.1 Solar Thermal Technology

Solar thermal works on the principle that a liquid flow in cylinders in the solar panel while the sun’s rays heat it. The plate panels or emptied tubes hold water and flow it through the water
heating system with the utilization of pumps. These are “active systems”. [6] Thermosyphon method is a method based on convection; it’s based on a passive heat exchange. [6] In other words, as the water warms up with it will push the cooler water. Private solar thermal heating us typically joined with reinforcement boilers to deliver year-round heat and hot water. Solar thermal energy is utilized to heat water and is also utilized for home heating through radiant floor, roof piping in radiant panels.

Figure 1: Solar Thermal Technology Diagram
3.5.2 Solar Photovoltaic Technology

Photovoltaic energy depends in the photovoltaic effect, by which a photo has an effect on a panel composed of semiconductors. Electrons are being released when the photon collides with semi-conductors. [6] This reaction leads to generate electricity through exposure to light. In these panels, the semiconductors have a form of thin layers that deliver electric current. These semiconductors contain the center element of solar cells and they capture the electric current changing it over electricity for the house or business.

![Solar Photovoltaic Technology Diagram](image-url)
3.5.3 Savings Potential

Many people are only acquainted with the PV solar systems for delivering electricity for their homes. They have no clue about the enormous funds’ capability of water heating by the sun. Solar thermal technologies were the principal utilization of solar energy and have good efficiency in energy and cost. [6] In addition, solar thermal systems are efficient to use as an alternative to using petroleum derivatives to heat water.

3.6 Pretreatment Methods in Biodiesel Production

Pretreatment implies the connected stages required in the plant as a way to process feedstock before their change to biodiesel. Such stages normally include decrement factors of negative effects on the biodiesel generation procedure, like “water, gums, suspended particles, polymers.” [7] In general, during alkaline transesterification, a formation of developed concentration is made which is caused by the presence of water. To get methanol and sodium hydroxide, a reaction between the developed soaps and the alkaline catalyst sodium methylate.

Some pretreatment methods used in biodiesel which are:

3.6.1 “Liquid Acid-Catalyzed” [7]

Feedstocks that have more than 10% of free fatty acid should be pretreated using a strong acid like sulfuric acid in order to reduce the free fatty acid level in the feedstock. This process comprises having a high temperature and high amount of methanol to be able to attain high conversions during a reasonable reaction time. However, the disadvantage of the acidic process is that the acid should be neutralized by the end of the process. Afterwards, the treatment of “the neutralized oil feedstock” [7] is done through alkaline catalyst and methanol to obtain biodiesel.
3.6.2 “Fatty Acid Distillation” [7]

It has for purpose to get rid of the low and high boiling contaminants that are contained in the feedstocks. This process goes through different steps that starts by getting the feedstocks implemented under inferior temperatures and high vacuum during a short time. This process contributes in decreasing the negative loss of free fatty acids.

![Fatty Acid Distillation Process Diagram](image)

Figure 3: Fatty Acid Distillation Process Diagram

3.6.3 “Blending” [7]

It is known that virgin oils are part of the low free fatty acid that can be mixed with inferior quality oils without really contributing in a high-quality production of biodiesel.

3.6.4 “Glycerolysis” [7]
It’s a process that has for purpose to reduce the content of the free fatty acids in feedstock through joining the FFAs with glycerin in order to obtain “mono-di-, and tri-glycerides”. The glycerin is directed back to a reactor where it is joined with the high free fatty acid feedstock. The emanating of the glycerolysis procedure is a low free fatty acids feedstock, commonly under 1% appropriate for soluble transesterification process under general working conditions.

*Figure 4: Glycerolysis Diagram*
3.7 Treatment

3.7.1 Transesterification Process

This procedure is known to be one of the easiest and fastest method for biodiesel production. In this method, triglyceride is reacted with catalysts, the triglyceride is presented as vegetable oil and the catalysts used can be either sodium hydroxide or potassium hydroxide that is dissolved in alcohol (either methanol or ethanol). We obtain from this reaction “fatty acid methyl esters” (biodiesel) and glycerin. [8] This method is considered to be economically efficient because the components used are cheap. For example, methanol Potassium hydroxide, and sodium hydroxide are considered to be low-priced because they’re easy to transport and store.

![Transesterification Reaction](image)

Figure 5: Transesterification Reaction

3.7.2 Supercritical Process

This method is considered to be one of the most modern methods in biodiesel production. The process can be completed without catalysts. A supercritical liquid is defined as a fluid that has temperature and pressure higher than its critical point. It can spread out through gas as solids or liquid through dissolving materials. These liquids are considered to be economically and environmentally efficient. Water, alcohol and carbon dioxide are considered to be supercritical fluids. A study was done by Saka, where oil was transformed to methyl esters using supercritical methanol at temperature of 350°C in 240 seconds. [8] The results showed that “the methyl ester
yield of the supercritical methanol method was higher than those obtained in the conventional method with a basic catalyst.” Not to mention, the main aspects influencing transesterification through supercritical process are the temperature, pressure and molar ratio between alcohol and oil sample.

Temperature is the most imperative factor in all parameters that influences the transesterification going through supercritical condition. In the research of Kusdiana & Saka, the transformation of triglyceride to methyl esters is moderately low due to the subcritical condition of methanol at temperatures of 200°C and 230°C. [8] In these conditions, methyl esters shaped are about 70 wt% for 1 hour treatment. Nevertheless, a high transformation of rapeseed oil to methyl esters with the yield of 95% wt% at 350°C in 4 min reaction time. [8]

Pressure is likewise very necessary; temperature and pressure work together since reaction pressure rises with the increment of temperature. Consequently, the impact of pressure on the transesterification is constantly related with temperature. High pressure rises the solvency of triglyceride, hence, “a contact at the molecular level between alcohol and triglyceride become closer at high pressure.” [8]

The impact of molar ratio between alcohol and oil sample is also really important in supercritical state. Higher molar proportion among methanol and triglyceride is recommended for transesterification reaction in supercritical condition. The reason can be that contact area between methanol and triglycerides are raised at the higher molar ratios of methanol. A study was made by Kusdiana showing the impact of the molar ration of methanol to a sample oil in the range between 3.5 and 42 on the yield of methyl ester framed for supercritical methanol treatments. [8] For a molar proportion of 42 in methanol, practically total transformation was
accomplished in a yield of 95% of methyl esters, while for the lower molar proportion of 6 or less, deficient change was apparent with the lower yield of methyl esters.

The advantages of this procedure are that it’s the reaction time is short, and it’s simpler cleansing of products and progressively effective reaction. [8] Although higher temperature, pressure and molar proportion between methanol and triglyceride are recommended for transesterification in supercritical state, energy consumption, and the overabundance of alcohol use are the disadvantages for this method to produce biodiesel.

![Figure 6: Supercritical Process Diagram](image)

### 3.7.3 Microwave assisted Process

Microwaves are electromagnetic radiations which are defined as a nonionizing radiation that impacts molecular movements like particle relocation, or dipole rotations, but not modifying the molecular structure. The frequencies of microwave range from 300 MHz to 30 GHz, normally, frequency of 2.45 GHz is recommended in research facility applications. The smallest degree of difference of polar molecules and particles with the ceaselessly changing magnetic field are being active by microwave irradiation. [8] The changing electrical field, which
combines with the molecular dipoles and charged particles, makes these molecules or ions have a fast pivot and heat is created caused by molecular friction.

Microwave procedure can be clarified for the biodiesel generation with transesterification reaction: the oil, methanol, and catalyst have both polar and ionic components. [8] Microwaves enact the smallest degree of difference of polar molecules and ions, prompting to molecular friction, which consequently lead to the possibility of initializing chemical reaction. Since the energy is combining with the molecules at quick rate, the particles don’t have sufficient time to relax and heat produced can be for short times and a lot more prominent than the total recorded temperature of the mass reaction mixture.

At the point when the reaction is done under microwaves, transesterification is effectively quickened in a sort response time. Subsequently, an exceptional decrease in the number of by-products and a short detachment time are acquired and significant returns of pure products are attained within a short time.

![Microwave Assisted Process Diagram](image)

*Figure 7: Microwave Assisted Process Diagram*
Post-treatment

Wastewater originating from biodiesel production comprises mostly of unreacted oil and fatty acid in emulsion shape and is produced in the transesterification procedure washing step. Based on how the efficiency of the system and its operation, sometimes remainder of glycerin that end up in the wastewater can be inevitable and this is normally results from the lack of management of the procedure operation which happens in division of glycerin from the biodiesel and in general, this situation can likewise represent a tremendous issue in the treatment phase. Since soluble base is utilized as a catalyst to accelerate the reaction process, the characteristics of the biodiesel wastewater is likewise expected to be exceptionally high in pH attaining almost 11 most of the time, which means that this would require pre-treatment phase to lower the pH near the neutral zone before the wastewater can be dealt utilizing bacterial biodegradation. Normally, for each metric ton of biodiesel fuel generated, one has to designate at least 200kg of crude wastewater for bioremediation and since more concerns originate from huge generation facilities particularly for large-scale biodiesel, efficient methods have been developed to treat this problem.

3.7.4 Natural Treatment (oxygen consuming)

Biological treatment utilizing bacterial biodegradation is really conceivable given that COD load isn’t at utmost which may finish up disturbing and repressing bacterial biochemical activity. Generally, with COD load lower than 10000 mg/l present in the wastewater, the microbes should have the capacity to manage it given that urea as like nitrogen source is given in a proportion enough to support its development. [9] However, utilization of this treatment choice present numerous difficulties since upset of the biological system is very exceptionally basic particularly in conditions whereby remainder of methanol, glycerin or soap as the by-
product can derive in high microorganisms. Moreover, with the fluctuating hydraulic load rate provided to the system which is normally observed in biodiesel plant also implies that control and change must be done quickly or the consequences will be severe, without a steady working system, things can be exceptionally hard to keep up. [9] Researchers have done additional investigations and deduced that there is a connection between high strong substances (oils and fats) in the wastewater and it can impact the development of microorganisms.

3.7.5 Anaerobic co-assimilation

Another option to treat the biodiesel wastewater is to utilize it “as a co-digestion feedstock with the glycerin” [9] or some other sort of organic waste utilizing the anaerobic digestion process to produce biogas. Normally the procedure is completed in a solitary stage digester comprising anaerobic sludge which can be acquired from “municipal sewage treatment plant.” The advantage of using this method is that anaerobic co-digestion is commonly more stable and can be controlled in a more efficient way while the methane generated in the reaction can likewise be used for other reasons. Based on the management of the system, biodegradability of the waste can be elevated between 95 to 98% with the majority of the energy produced from COD decrement were consumed to deliver methane. [9] Methane yield coefficient which is the regular term utilized to statute efficiency of the treatment method can vary, however; a general rule can be in the scope of 250-300 ml of methane expected per gram of COD expelled. Normally, anaerobic co-digestion of glycerin together with the biodiesel wastewater treatment pursues two step procedure: the first one requires acidification, the second one comprises electrocoagulation before the wastewater is sustained to the digester.
3.7.6 MBR Technology

Recently, with membrane bioreaction technology, being known for the decrement of membrane production cost and developed quality, studies have moved spotlight towards to determine if it can afford a feasible treatment choice for biodiesel wastewater. The structure thought can be distinctive relying upon where the membranes are present but mainly nowadays included the submerged kind with areas or partitions made acting as pre-treatment phase before the wastewater attains the membrane. [9] So far, this innovation has not been tested full scale in biodiesel plants and its utilization is for the most part restricted in small communities. However, progress has been made throughout the years, it could conceivable that with further enhancements combined with new technologies dependent on membrane systems, it can be embraced to effectively treat the biodiesel wastewater.

4 STEEPLE Analysis

4.1 Social Aspect

The production of biodiesel is a convenient way to encourage society to be more responsible about the environment. In addition, it will also promote the use of solar energy and water treatment as a way of protecting the environment.

4.2 Technical Aspect

We will be working on the treatment and post treatments phases of the biodiesel production. In the treatment, we will be focusing on the choice of water treatment type that we can recycle for washing the biodiesel. In addition, we will also be working on the type of solar system either PV or thermal and the wastewater treatment system based on their efficiency in the project.
4.3 Economical Aspect

The process of this production comprises using a renewable energy technology as a source of heating for the pre-treatment and treatment phase. However, the cost of thermal technology can be expensive. This is why, a cost analysis has been established to analyze the difference between using thermal energy and normal electricity to see the cost-efficiency of the thermal energy’s use.

4.4 Environmental Aspect

Diminishing greenhouse emission of gases. The main purpose of this process is to consume the less energy possible either in solar energy or water treatment. Biodiesel production as a concept, it includes using low consumption of energy with a high fuel efficiency. It is also beneficial to affect less the global warming.

4.5 Political and Legal Aspect

The government doesn’t mention in any legal or political document about the production of biodiesel in Morocco.

4.6 Ethical Aspect

This process helps in sensitizing people about the importance of environment. This project contributes in encouraging people to use waste products. In addition, the whole project is meant to protect the environment and people from pollution.
5 METHODOLOGY

5.1 Project Description

The purpose of this project is to find optimal choice to provide heat concerning the pre-treatment, the treatment, and optimal choice for the water treatment system to for the post-treatment of this process. First of all, we needed to understand the different of this project: chemical, biological, thermal, and economical. This project will be addressed to Ifrane’s community. Our project follows multiple steps, first we had to understand the concept of transesterification reaction process. Thus, we had to understand the process of the three phases. In this project, we focused mainly on the optimal system to choose for the energy resource and the water treatment system.

This project follows three phases:

Pre-treatment

- Reacting 40L of Methanol with 1.73 Kg of Potassium Hydroxide (catalyst)
- Agitating the reaction to get the solution after 30min, then turned off the agitator.
- Filtering the waste cooking oil to remove all the food chunks.
- Heating the waste cooking oil at 50°C

Treatment

- 200L of waste cooking oil is moved to another tank
- Methoxide solution is also added to the same tank with the waste cooking oil.
- Heating the waste cooking oil with the methoxide solution at a temperature maintained at T=55°C
- The heating process continues for 2 hours, then the agitator is turned off.
- Rising the temperature to 70°C for the methanol recovery.
- Continuing the heating process then lowering the temperature to 40°C.
- Letting the mixture to settle down for 24h.
- The mixture is separated into and upper layer (methyl esters) and lower layer (glycerin)

**Post-Treatment**

- Washing the biodiesel with water:
- Adding 400l of boiled water to the tank and agitating the tank for 1 hour.
- Letting the mixture to settle for 24h.
- The mixture is separated into two layers (aqueous and organic)
- Drying the biodiesel:
- After one hour, biodiesel is being dried using two filters.

In this project, I had to look for the heat source used in the pre-treatment and treatment phases, and the optimal system to treat the wastewater gotten from the biodiesel production in the post-treatment phase.
5.2 Type of Solar Energy

For the heat energy we had to know which kind of energy are we going to use: thermal or photovoltaics. For that we had to calculate the heat energy using the heat sensible formula. We used the data given for the project which are the mass of the substances used and the temperature.

We had to look for the specific heat capacity of each substances which was hard to obtain the data for all the substance because we had difficulties to know which one to use and how many equations we are going to use.

For that we had to calculate sensible heat change for each phase:
<table>
<thead>
<tr>
<th>Phase</th>
<th>Process Description</th>
<th>Mass (Kg)</th>
<th>Specific Heat Capacity (kJ/(kg K))</th>
<th>Temperature Change (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heating Waste Cooking Oil</td>
<td>185.6</td>
<td>1.67</td>
<td>50-15= 35</td>
</tr>
<tr>
<td>2</td>
<td>Heating the methoxide solution</td>
<td>33.41</td>
<td>2.5</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td>Continue the heating reacting the waste cooking oil with the methoxide solution</td>
<td>219.02</td>
<td>2.5</td>
<td>55-50=5</td>
</tr>
<tr>
<td>4</td>
<td>Methanol Recovery</td>
<td>219.02</td>
<td>2.5</td>
<td>65-55=10</td>
</tr>
</tbody>
</table>

Table 1: Phases Characteristics

\[ Q_{\text{sensible}} = m \times c_p \times \Delta T \]

We have \( m_{\text{WCO}} = \rho \times V = 928 \times (200 \times 10^{-3}) = 185.6 \text{ Kg} \)

For \( m_{\text{methoxide}} = 31.68 + 1.73 = 33.41 \text{ Kg} \)

For \( m_{\text{reaction}} = 185.6 + 33.41 = 219.02 \text{ Kg} \)

\[ Q_{\text{WCO}} = m \times c_p \times \Delta T \]
\[ = 185.6 \times 1.67 \times 35 = 10848.32 \text{ KJ} = 3 \text{ kWh} \]

\[ Q_{\text{Methoxide}} = m \times c_p \times \Delta T \]
\[ = 33.41 \times 2.5 \times 55 = 4593.875 \text{ KJ} = 1.2 \text{ KWh} = 0.60 \text{ kWh} \]
\[ Q_{\text{Reaction}} = m \times c_p \times \Delta T \]
\[ = 219.01 \times 2.5 \times 5 = 2737.625 \text{ KJ} = 0.74 \text{ kWh} \]
\[ Q_{\text{Reaction}} \times 2 = 1.48 \text{ kWh} \]
\[ Q_{\text{Methanol}} = m \times c_p \times \Delta T \]
\[ = 219.01 \times 2.5 \times 10 = 5475.25 \text{ KJ} = 1.48 \text{ kWh} \]

\[ Q_{\text{sensible}} = Q_{WCO} + Q_{\text{Methoxide}} + Q_{\text{reaction}} + Q_{\text{Methanol}} = 3.0 + 0.60 + 1.48 + 1.48 = 6.5 \text{ kWh} \]

Thus 6.5 kWh is the power that is going to be delivered in the whole process.

Now we have to decide which type of energy we’re going to use: either thermal or photovoltaic.

In this project, based on our calculations for the heat and power production, we decided to take thermal energy as a source of heating because:

- Unlimited use of energy, with no charges [10]
- No CO2 emission during the process [10]
- Cost reserve funds: “up to 60% less energy to heat water, up to 35% less energy for space heating.” [10]
- Diminished utilization of petroleum derivatives. [10]
- Thermal system technologies can be incorporated into existing systems. [10]
- Thermal technologies are effective even in winter. [10]
Thus, we will be using solar collectors more precisely flat plate collectors since they have advantages that work for our project which are:

- Low cost in purchasing
- Lower maintenance and fix costs
- Recommended to be appropriate for low temperature systems: to afford boiled water or to maintain heating
- Elevated efficiencies with ideal sun powered yields

The next step was to know how many solar panels we have to use for this project based on the power produced in the whole process. Thanks to Dr. Lghoul who provided me with the RETSCREEN software that analyze the thermal efficiency of the process taking into consideration the region, country, and city of the place’s installation of the solar panels.

Using this software, we started by entering the city where will be putting the solar panels, which is Ifrane.

![Figure 9: Input of Information in the RETSCREEN Software](image-url)
As you can see in the figure above, after entering the name of the city, we got different information, such as the average temperature, the daily solar production monthly and annually. Afterwards, I had to enter all the information needed concerning the process so we can get more specific data concerning the thermal efficiency and the number of solar panels.

Here is below a figure of the specifications of the project entered in the software.

\[ \text{Figure 10: Input of the Project's Specification on RETSCREEN} \]

Finally, after entering all the information of the project, we got the number of solar panels we will be using which is: 5

Here is a screenshot of how we got the number of solar panels.
As you can see from the figure above, and according to the information entered in the software, we need 5 solar panels that can produce an amount of 6.55kWh (the power needed in the project).

5.3 Cost Analysis

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Thermal Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (MAD/kWh)</td>
<td>1.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>
From the software, we got the price of 1 kWh produced by the thermal solar panel which is 0.5 MAD and knowing that in Ifrane, the price is more than the double; 1.2 MAD. This comparison proves that the use of thermal energy is largely more efficient than the normal one since both of them produce the same amount of power but have different price when it comes to the monthly price. The electricity’s price is 156 MAD which is way expensive than the thermal one. Thus, we can conclude that in addition to thermal energy being environmental and consuming less energy it is also considered to be cost efficient.

In addition, we also calculated the return on investment, and according to the information we put in the RETSCREEN software and the price we got for 1kWh using the solar thermal energy, we concluded that we will be getting the return on investment after almost 4 years. Here is a graph that describes the return on investment throughout the next 20 years.
Figure 12: Return on Investment Graph

5.4 Wastewater Treatment

For our project we are going to be using coagulation/flocculation as a way to treat water. Since we couldn’t do the experiment in the lab because of the lack of equipment so we can’t know the quantity of the wastewater produced after the biodiesel process. Thus, we did several research in order to find an experiment where they used this method to see the results as a proof of its efficiency. Consequently, the reason of this choice is that the combination of these two techniques resulted in removing about 78.5% of organic carbon in an experiment done in Brazil. [12] Coagulation/flocculation helps to optimize the initial pH of the solution. They used aluminum sulfate as coagulant since it has 99.5% of purity and is not expensive unlike ferric
chloride, and it’s also efficient when it comes to decrease contaminations in wastewater with pH 6-8. [12] It is additionally generally utilized for displaying high coagulating efficiency, accessibility, and easy to handle. “They utilized Engeclean as the flocculant at concentrations of 20 and 76.7 mg/L.” [12] Approximately 0.45 mg/l of the alkalizing agent calcium carbonate was used with the purpose to avoid in change in pH after the treatments.

The CF test was done utilizing 300 mL tests of crude and “synthetic effluent separately.” pH values were balanced and changed between the scope of 5 to 7.5 utilizing 5 M sulfric aci and 0.1 M sodium hydroxide. 5% of aluminum sulfate is used as a coagulant and the polyelectrolyte CA 35 at 25% focus as a flocculant. The quich blend time (100 rpm) was 1 moment and 20 minutes for the moderate blending (40 rpm). [12] After the settling of the flocs shaped, 100 mL tests of the treated profluent’s seputernatant phase were gathered for further TOC investigation to decide the evacuation rate. In the wake of distinguishing the ideal coagulating pH for most astounding TOC evacuation, test were rushed to the following treatment venture to asses the DSA (Dimensionally Stable Anodes) and BDD (Boron Doped Diamond) electrons. [12] This method is considered to be the most efficient one because it contributes in the increment of yield by more than 60%.
6 CONCLUSION AND FUTURE WORK

The objective of this capstone project was to look for an optimal type of solar energy to heat the pre-treatment and treatment phases for the biodiesel production process. Afterwards, we had to look for the best system for treating the wastewater treatment obtained from the biodiesel production. For this, we had to conduct a thorough research and try different calculation methods to get accurate results for the heating process.

On the other hand, from the study and research we’ve been doing during this semester, we strongly believe in the feasibility of the project. Throughout the semester, we only analyzed the choice of each phase theoretically. Nonetheless, this won’t stop us to plan for a future for our project and develop it by applying it in the real life by doing the experiment to get accurate data concerning the water treatment method.
7 REFERENCES


