Biofuels: The Potential Opportunities and the Realistic Limitations

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Introduction:

The ways in which humans harvest energy are getting more efficient every day. With biofuels, we have the ability to create a greener and more accessible alternative to traditional fossil fuels. Biofuels can be harvested locally to help stabilize the economy and increase local job opportunities. They emit less pollution if the production is done correctly, lowering carbon amounts going into the atmosphere. We will explore how some countries are already implementing major biofuels into their communities to use instead of regular gasoline, and how this may be an easy step to creating a more environmentally-friendly future.

Although production emits far less pollution into the air, biofuels may not be as green as they are made out to be. Producing biofuels are water intensive, a driver in deforestation for land, reduces biodiversity abundance of an area via mono-crops and habitat destruction, and pollutes the growing area with chemical fertilizer run off. From a pure functional perspective, biofuels when combusted will produce more nitrogen oxides (NO_x) emissions than traditional petroleum energy, thus making one question how beneficial this alternative energy option may be.

Types of biofuels/production/usage:

Biofuels are classified under four different generations based on their origins and production methods (Aro, 2016). First-generation biofuels are derived from food crops grown on arable land. These crops are grown with the sole intention of being used for fuel production. The sugars, starches, and oils from these crops are used to produce biofuels such as biodiesel or ethanol.

Second-generation biofuels are made with non-food crops or biomass waste. These fuels can either be burned directly for heat and electricity, or further refined into other biofuels. This includes woody crops such as switchgrass, which is grown specifically for biofuel production, as well as left overs from food production such as bagasse (sugar cane husk), and waste from forestry and lumber production. Waste vegetable oil - often converted into biodiesel - and municipal solid waste are also used as feedstocks for second-generation biofuels (Biofuel.org.uk, 2010).

Third-generation biofuels are produced using oil rich algae. These are capable of much higher yields and can be used to produce more types of biofuels than second-generation biofuels. For example, the oils can be refined into biodiesel or components of gasoline. With the use of genetic manipulation, algae can also be modified to produce a variety of fuels directly. These fuels include biodiesel, butanol, gasoline, methane, ethanol, vegetable oil, and jet fuel (Biofuel.org.uk, 2010).

Fourth-generation biofuels do not require the destruction of biomass for production. These biofuels include electrofuel, which is a liquid or gas fuel that stores electrical energy in its chemical bonds, and solar fuels, which are produced using solar heat to drive chemical reactions (Electrofuel, 2019; Solar Fuel, 2019).

Biodiesel is a diesel fuel alternative that can be used in diesel engines for both motor vehicles and industrial equipment, as well as generators or furnaces; it is often blended with traditional diesel or in some cases as pure biodiesel. Most modern vehicles (1994 onwards) can use biodiesel without requiring any modification. Biodiesel blends are labeled as B*n* where *n* refers to the percentage of biodiesel in the blend; pure biodiesel is known as B100 or "neat biodiesel" (Natural Resources Canada [NRCAN], 2018). Using pure biodiesel during the winter may cause maintenance or performance problems because the fuel can become more viscous at lower temperatures (Biofuel, 2020). Biodiesel can be produced from vegetable oils, animal oils or fats, or waste cooking oil, and is created by a process called transesterification(NRCAN, 2018; "What is Biodiesel", n.d.). This process requires a triglyceride (the fat or oil) an alcohol (typically methanol or ethanol) and a catalyst (potassium hydroxide or sodium hydroxide). The triglyceride fatty acid reacts with the alcohol in the presence of the catalyst to form mono-alkyl esters, the biodiesel, and glycerol. Biodiesel has several advantages over traditional diesel fuel: pure biodiesel is biodegradable, biodiesel can be produced from some waste products, it has reduced greenhouse gas emissions when compared to traditional diesel, and it is less toxic than traditional diesel.

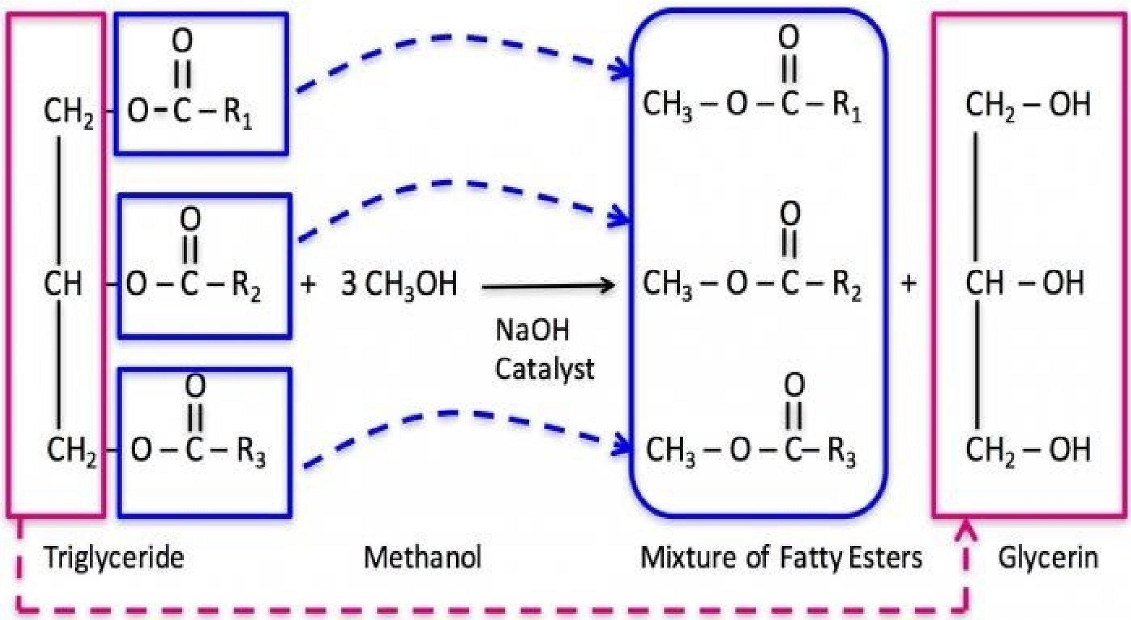

Figure 1. Chemistry of biodiesel production. (John A. Dutton e-Education Institute, n.d.)

Green diesel is similar to biodiesel in that they use the same feed stocks, however the process does not produce any glycerol. Green diesel is produced through a process called hydrocracking. High pressure and temperature is used, with hydrogen gas as a catalyst, to break down the larger hydrocarbon chains found in vegetable oils, into shorter chains used in diesel fuel. Green diesel has the same chemical properties of traditional diesel and requires no modifications to diesel engines or infrastructure (Biofuel, 2020).

Biogas is a fuel that is comprised primarily of methane gas (CH_4), as well as carbon dioxide (CO_2) and smaller amounts of hydrogen sulfide (H_2S) (Ruan *et al.,* 2019). Biogas is produced via the breakdown of organic matter in a process called anaerobic digestion (Ruan *et al.,* 2019). Biogas is produced in an anaerobic digestion chamber, where organic matter, that can include raw materials such as agricultural and municipal waste, manure, and crops, undergoes fermentation where the biowaste and material are converted to biogases (Ruan *et al.,* 2019). Most biogas is produced from landfills and wastewater treatment facilities, where the fermentation process is monitored before the methane is refined and purified before being used (Farmers Guardian, 2009). Although unsuitable for use in machinery due to the corrosive and unstable nature of the constituents, biogas is most actively used for heating and energy purposes, such as cooking, or in a gas engine to convert energy into electricity and heat (Abatzoglou & Boivin, 2009). In order to be utilized as an effective vehicle or machinery fuel, the biogas must undergo an upgrading process to concentrate the methane (“Biofuel,” n.d.). There are four methods of biogas upgrading, pressure-swing absorption, selexol absorption, amine gas treating, and the most commonly used, water washing (“Biofuel,” n.d.). Following the upgrading and cleaning processes the biogas is concentrated to the same standards as fossil natural gas, producing what is termed biomethane (“Biofuel,” n.d.).

Synthetic gas, otherwise known as syngas, is a mixture of hydrogen (H_2), carbon monoxide (CO), and carbon dioxide, and is commonly used as an intermediate in both the production of synthetic petroleum and diesel, and the conversion of certain biomass to fuel (“Syngas composition,” n.d.). Syngas is often produced by the large amounts of waste gas produced in industrial settings (“Syngas,” n.d.). Syngas may be produced via many gasification procedures, but the most common is by steam reforming (“Syngas,” n.d.). In this process shown below, incandescent coke reacts with steam in a three step process to produce carbon monoxide and hydrogen gas, or syngas. (El-Nagar & Ghanem, 2019).

$$CH_4 + H_2O \rightarrow CO + 3\ H_2$$

Equation 1. Conversion of methane and water into carbon monoxide and hydrogen for syngas production.

The syngas produced can be converted to diesel fuel by the Fischer-Tropsch process, where the syngas reacts with metal catalysts to produce long alkenes (“Fischer-Tropsch process,” n.d.).

$$(2n + 1)\ H_2 + n\ CO \rightarrow C_nH_{2n+2} + n\ H_2O$$

Equation 2. Conversion of hydrogen and carbon monoxide into alkenes and water.

The carbon monoxide produced from the gasification process can then undergo further steam reforming to produce carbon dioxide and hydrogen, and these products can be used to produce methanol (El-Nagar & Ghanem, 2019).

$$CO_2 + 3\ H_2 \rightarrow CH_3OH + H_2O$$

Equation 3. Conversion of carbon dioxide and hydrogen into methanol and water.

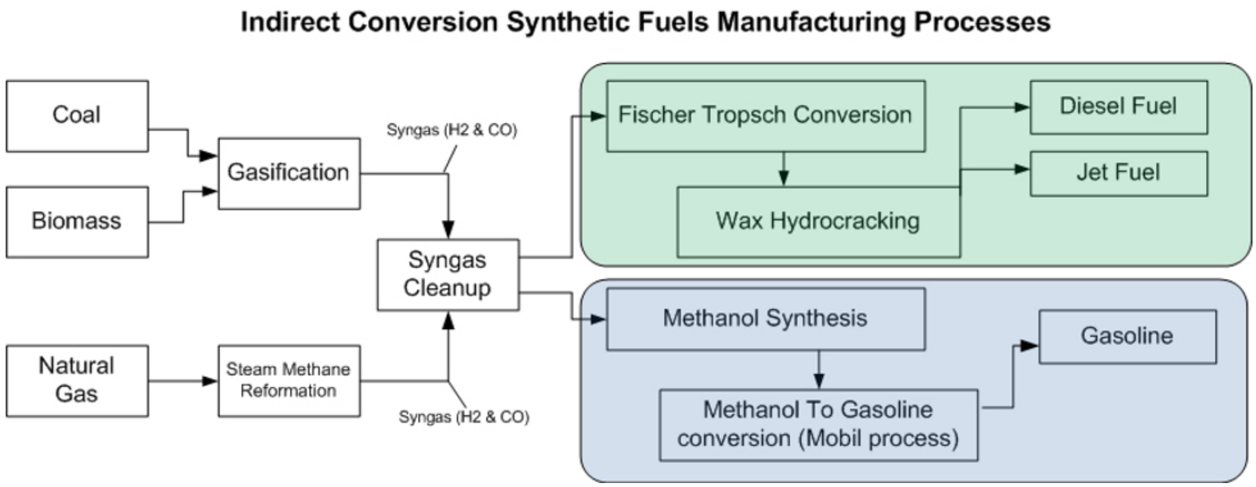

Figure 2. Synthesis pathways of syngas production and refinement ("Syngas," n.d.)

Ethanol is the most produced bioalcohol in the world, and is produced from the fermentation of starch or sugar, most commonly from corn grain in the United States (Eckley Selin & Lehman, 2018). During fermentation, sugars – primarily glucose – are converted to ethanol and carbon dioxide ("Ethanol fuel," n.d.)

$$C_6H_{12}O_6 + H_2O \rightarrow 2\ C_2H_5OH + 2\ CO_2 + \text{heat}$$

Equation 4. Conversion of glucose and water to ethanol, carbon dioxide, and heat.

Ethanol may also be industrially produced by the catalyzed hydration of an ethylene double bond. ("Ethanol fuel," n.d.)

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

Equation 5. Conversion of ethylene and water into methanol.

As ethanol only has half of the gasoline gallon equivalent of standard gasoline, it is most commonly used as a gasoline additive rather than as a stand-alone fuel source (Eckley Selin & Lehman, 2018). Today, gasoline sold at a standard gas station in the United States or Canada is composed of a blend of 10% ethanol ("Ethanol fuel," n.d.).

Along with bioethanol, other alcohols can be produced that can be utilized as fuel. Biomethanol can be produced from syngas and biomethane. Syngas can be converted to biomethanol by catalytically converting it using copper oxide, zinc oxide, or chromium oxide. Landfills are a large source of biomethane, which can be converted to syngas through a pre-treatment and compression process and then converted to biomethanol. Bioglycerol can also be feasible as it is a by-product of biodiesel production. Glycerol does not burn easily so bioglycerol is likely to be used for non-combustion uses (Luque, 2011). Bioalcohol can also be produced through the conversion of biomass by microorganisms. The most common pathways for this are the glucose conversion by yeast where the product is ethanol. As well as the processes performed by anaerobic bacteria that results in ethanol as well (Basen *et al*., 2014).

Bioethers are a category of biofuel that is characterized by having a molecular makeup that includes an oxygen atom with a carbon atom on either side, otherwise known as an ether group ("Bioethers", n.d.). Bioethers are commonly used as a fuel additive to improve engine functioning but have also been investigated as a fuel alternative ("Bioethers", n.d.). Methyl-tertiary-butyl-ether (MBTE) and ethyl-tertiary-butyl-ether (ETBE) are ethers derived from fossil fuels that are currently commonly used fuel additives (Methyl-tert-butyl-ether., n.d.). Dibutyl ether (DBE) and oxymethylene ethers (OME) are second-generation biofuels that have been studied as an alternative to diesel fuel or as an agent that can be mixed with diesel (Damyanov *et al*., 2018). These bioethers are produced from lignocellulosic biomass by either biomass pulping (DME) or gasification (OME). During biomass pulping the cellulose, hemicellulose and lignin that makeup lignocellulose are separated and fermented, DBE is produced by the dehydration of resulting butanol (Damyanov *et al*., 2018). Gasification involves converting the lignocellulosic biomass into a gas through a sequence of thermo-chemical reactions ("Biomass Gasifier", n.d.).

Straight vegetable oil (SVO) has also been investigated as a fuel alternative in diesel engines. However, because of its viscous property, its usage is restricted to single-cylinder engines or engines that have been modified to reduce the viscosity (Misra & Murthy, 2010). Vegetable oils consist of triglycerides composed of a carbon backbone and hydrocarbon chains, with varying oils containing different length chains (Misra & Murthy, 2010). Vegetable oil is produced by removing the oil from the plant by mechanical or chemical extraction. Mechanical extraction requires physically crushing the plant while chemical extraction uses a solvent, which is later evaporated out ("Vegetable oil", n.d.). Vegetable oil can be considered a second-generation biofuel when waste vegetable oil is used as it has already fulfilled its purpose as a food source ("Second Generation Biofuels", n.d.).

Pros of Biofuels:

The use of biofuels originated in place of non-renewable resources that have been running out since humans started using them. The first and most obvious advantage to using biofuels is that they are more sustainable than other energy options that exist currently. Many countries including Canada are extremely dependent on fossil fuels. Diverging from heavy pollutants is required in order to reach lower carbon emission goals in the coming years. Some research states that biofuel use can be carbon neutral, and other research expands to say this is only if it is done correctly (Correa, 2019). Discussion about the problems with incorrect biofuel use and its repercussions will be seen in the next section about possible downsides. If harnessing energy from biofuels is done correctly, decreasing the amount of carbon in our atmosphere by this margin would be overwhelmingly positive. Combusting bioethanol reduces carbon monoxide emissions, and other plant-based fuels reduce carbon emissions as well (Nunez, 2019). Global biofuel output needs to triple by 2030 in order to meet the International Energy Agency's targets for sustainable growth according to Nunez (2019).

Brazil is one of the leaders in bioethanol production and has invested in producing energy in an environmentally friendly way. Crops of sugarcane are harvested to burn for ethanol production and can be used as motor fuel. Gasoline in Brazil has more ethanol per litre than gasoline in North America does (Nunez, 2019). This has been implemented in order to move away from fossil fuels and make use of their locally created resources. Most new cars being sold in Brazil have a flex-fuel option that allows them to run with this adapted form of gasoline (Crago, 2010). Other countries could make small changes like this on the journey to completely leave behind other forms of fuel. There is a low production cost of ethanol from sugarcane, and Luo *et al.* (2008) assess the impacts of harvesting bioethanol to be more environmentally friendly overall than using traditional fuel types.

Oil spills and other direct pollution due to contaminants are major problems currently being faced. Canada's debate about pipelines is a major source of political backlash, because of the devastating effects of oil spills on land or in the oceans. If biofuel was to be spilled in an ecosystem as a result of an accident, the fuel would biodegrade. It would not persist in the ecosystem, meaning long-term damage to the environment would be avoided (Strogen, 2013). This is a huge upgrade from the dangers of transporting traditional oil or gasoline. Transportation of biofuels is not yet efficient, but researchers are working on solutions that will ultimately be much less hazardous than moving oil across the country or world.

Transport risks can also decline by producing biofuels domestically. Oil must be found and refined, then moved to places without access to fuel. Biofuels could be created in many places, leading to less import and export of fuel. This makes dependents less vulnerable to supply disruptions than the current system (Crago, 2010). Societies rely on the import and export of oil to sustain the economy and infrastructure, as is seen in Alberta and British Columbia. If oil were to stop being imported tomorrow, it would cause a devastating impact on both provinces. Creating fuel locally solves this problem and provides jobs to those who live in the area as well (Correa, 2019). When the workforce is community-based, it creates more economic stability that Canada does not currently possess.

Biofuels can be burned in standard internal combustion engines with limited adjustments to the mechanics (Carneiro, 2017). This is superior to switching to electric cars or utilizing hydrogen as an energy source because there would require a complete overhaul in how we make vehicles. Many types of biofuel perform well in engines, and they may actually lead to less maintenance overall (Carneiro, 2017). Biodiesel specifically can be used in current diesel engines with only minor changes, making it an easy switch for those who own these vehicles. Although diesel vehicles make up a small percentage of cars on the road, this could be a first step into making biofuels mainstream in more countries. One of the negatives that will be explored in this paper is the cost of changing to biofuels. They do have the potential to go down in price once they are integrated into the mainstream, and we see this in Brazil (Correa, 2019).

While using biofuels may come at an increased cost, the extra money spent is worth it in order to implement fuel options that will save the Earth. The use of alternative energy sources is a growing sector with a defined goal of decreasing fossil fuel emissions and pollution. There may be some problems with the current system in place to use biofuels, but it is the birth of a new way of using energy that is becoming more efficient, cost-effective and accessible all the time. The potential for alternative biofuel development is unlimited in the coming years. With increased research, funding, and interest, the use of biofuels could be a huge turning point in the fight against climate change. A focus on technological development is imperative if this option is to become mainstream enough to make a sizable environmental impact. The move towards sustainable energy options may be slow, but it could be a major upgrade in the long run.

Problems with Biofuels:

Production- Biochemical

As stated in the previous section, using corn, wheat, or vegetable oil is in direct conflict with the world's growing food demands, and utilizing the cropland for biofuel can be viewed as unethical. As a result, energy is being directed at converting wood waste from milling operations to burnable fuel. The main problem with this is optimizing this process so that it is energetically an environmentally favourable. This is due to the biochemical structure of wood. It is predominantly composed of robust soft tissues, such as cellulose, hemicellulose, and lignin. In order to be fermented into bioethanol, wood products must be broken down into simple monomers or dimers. Plants often have defense mechanisms that increase the production of these molecules in times of stress which adds to the difficulty (Campbell and Ellis, 1992). This energy intensive process often leads to bottlenecks in the biofuel production process, and makes it less viable as an environmentally sustainable replacement to fossil fuels (Mosier, 2005). There are a number of proposed solutions to this problem, such as genetically modifying the composition of lignin to make it more penetrable, decreasing the adhesion between cell walls, and pretreating the wood (Ho *et al.,* 2014). Researchers have also proposed using wood as a porous media to facilitate reactions of other potential biofuels by lowering the activation energy of the reaction (Kastner *et al.,* 2012).

Production- Transportation of goods

There are two main challenges for biofuels in terms of transportation logistics: 1. transportation of the feedstocks to the processing plant and 2. transportation of processed biofuels to potential consumers. One paper compared the amount of energy required for transportation and conversion to methanol of energy crops and fossil fuels and found there to be approximately 25% more energy required for the conversion of biofuels. However, this was largely due to conversion inefficiencies, not transportation factors (Hamelinck *et al.,* 2005). They found that the transportation was optimized with a higher density (less loss of matter) of biofuel feedstock and lower travel distances. They found cost per kilowatt-hour (kWh) was similar if feedstocks were imported from Latin America in pellet form and also mentioned that overall it would lead to much less CO2 emissions, assuming land-use change has minor impacts on CO2 emissions. Another study stated the shipment of densified biomass is similar to shipping grain, and states that the optimal transportation method depends on distance, with truck, train, and barge being the most efficient for short to long distances, respectfully (Gonzales *et al.,* 2013).

After the feedstocks are converted to ethanol, they go to blending facilities where they are mixed with gasoline and distributed to consumers. Thus the challenges with transportation are the same as with ethanol. The blended gasoline tends to separate in pipelines and can be corrosive, which limits transport to vehicles (Kang *et al.,* 2009). Again, the shorter the transportation distances required, the more energy and CO2 efficient this process is.

Studies have also looked at the overall greenhouse gas (GHG) emissions and energy expenditure of biofuels. When looking at *Miscanthus* grass biofuels, researchers found that the distribution system required 5x the amount of GHG and energy compared to petroleum (Strogen and Horvath, 2013). Obviously, this will need to be much more efficient in order for biofuels to become viable in the long term.

Economic- Effect on other Industries

One major concern, especially among Canadians, is how biofuels would affect the prices of oil and gasoline in this country and, therefore, the economy. One economic benefit proposed by the Canadian government is the use of agricultural products and waste, which benefits farmers. Currently, the low oil prices are making it very challenging for biofuels to penetrate the market (Robredo *et al.,* 2017). This prevents biofuel companies from selling their product, resulting in surpluses and too much supply, further dropping the prices of both biofuel and oil. With the push for green energy solutions, biofuel plants are often subsidized by governments, and become deadweight when they aren't profitable. Currently, the scale of biofuels in relation to oil products is so small the impact will not be massive, but that could change as the industry continues to grow.

The designation of land for biofuels can also impact the food economy. Many techniques include the use of commodities such as corn and wheat. As a result, the demand for these products increases and so do the prices. This is beneficial to farmers in these areas, however, it may be detrimental to those living off of tight food budgets. Obviously the use of other feedstocks such as wood and agricultural waste will have a smaller impact on the economy.

Switching to Biofuels

Economic- Cost of Switching to Biofuels

Some biofuels, such as biodiesel, require little to no modifications. Occasionally, biodiesel can contain methanol which can ruin rubber pieces in an engine's fuel system, which would need to be replaced before using biodiesel (Linhares, 2016). To expand this on a larger scale, only about 3% of auto sales in the United States were of diesel engines in 2015 (Chambers and Schmitt, 2015). The cost of transitioning gasoline vehicles to biodiesel-compatible vehicles would be extremely cost intensive. This would be incredibly risky as many countries are on the verge of banning the use of diesel engines and potentially all non-electric vehicles over the next few decades. This will result in poor long term returns on the massive investment it would require to produce more biodiesel compatible vehicles. Even large semi-trucks may have limited lifespans as companies such as Tesla continue to innovate and produce viable long-haul electricity-powered alternatives. The International Institute for Sustainable Development did a report investigating the capital investment that was required to construct infrastructure for biodiesel and ethanol in Europe. They found for 88 facilities in 2011, the cost was around EUR 17 billion for capital investment and operations, with biodiesel at a significantly lower price per litre than fossil fuels (Charles *et al.,* 2013). Renewables currently make up 17% of the gross energy consumption in Europe (Camdessus, 2019) Assuming the relative amounts of hydro, solar, wind, and biofuels remained the same, An increase to 51% renewable energy would require the amount of energy from biofuels to triple, for an additional investment of EUR 35 billion annually. This does not factor in the costs for the removal/modification of current 'dirty' energy plants, which will require additional investment and energy expenditure.

Even though direct use of biofuels may be limited, the energy consumption around the world is going to continue to rise, and the use of biofuels to generate energy may be crucial to combat emissions associated with this growing demand. This is generally done in two ways: 1. Directly burning biomass to create steam which powers the turbine or 2. Production of syngas that is used in a gas turbine for energy production.

Table 1. Unsubsidized levelized costs of electricity from different sources in the USA in 2017

Type of fuel	**Unsubsidized Levelized Cost ($/ MWh)**
Coal	$60-143
Gas Combined Cycle	$42-78
Solar PV- community	$76-150
Onshore Wind	$30-60
Biomass- direct	$55-114
Nuclear	$112-183

According to the table above, electricity generated directly from biomass is currently more expensive than gas combined cycle and onshore wind but cheaper than nuclear, solar, and coal (Waxler, 2017). The price of alternative energy sources have been consistently dropping while traditional fuels are relatively stagnant.

Environmental

Although there are many benefits to biofuels, there are also many downsides as well. Such as, increased NOx emissions, deforestation, large water consumption, increased chemical fertilizer pollutants, threats to biodiversity, and threats to food security. According to Alptekins (2017) study, biofuels when combusted may produce less carbon monoxide (CO) and total hydrocarbon (THC) emissions than traditional petroleum; However, biofuels produce more nitrous oxide (NO_x) emissions than petroleum does. These results have been confirmed by other studies seen in the Walsh (2008) article.

In order to produce enough crops as a feedstock for biofuels at a global scale, large amounts of land are required to produce these crops for biofuels. Thus, more deforestation and land is needed (Rosenthal, 2007). This in a way contradicts the purpose of a “biofuel” as a standing forest produces oxygen (O_2) and stores Carbon Dioxide (CO_2) via photosynthesis both of which are needed to offset green-house gas emissions (Wikipedia). Crops used for biofuels such as Corn and Palm oil plantations are huge drivers in deforestation and biodiversity loss

(Rosenthal, 2007). Land use change in agriculture decimates biodiversity and other ecological processes; Thus, lowering the Alpha (local) diversity of a specific area. Additionally, agricultural crops such as corn and palm introduce mono-cropped species plantations which lowers the genetic diversity of the area and reduces habitat for native species. Furthermore, to produce enough crops for ethanol and other biofuels, large amounts of chemical fertilizers are required to grow the crops fast enough for the growing demand for these "Biofuels". Consequently, these fertilizers such as nitrogen, pollute the surrounding environment, and can cause drastic effects on an ecosystem, such as nitrogen deposition which can create dead zones in waterways (Mckenna, 2009).

Not only does harvesting biofuels pollute and destroy ecosystems but it also consumes huge amounts of water. Biofuels such as ethanol require a lot of corn, which as a plant requires a large amount of water. Depending on where ethanol corn is grown, water consumption varies from 5- 2138 litres (L) of water for 1 L of ethanol (Mckenna, 2009) refer to figure 1. This alone has its own detrimental effects to the surrounding area as it consumes from local water sources that may put certain places at risk of drought (Mckenna, 2009). The discussion of biofuels, like many other alternative energy sources exists as one that is inherently political, typically involving issues of social, ethical and environmental nature. Chief among these areas tends to be the debates regarding the "food vs. fuel" aspect of biofuel production and issues of land rights infringement.

The core tensions within the "food vs. fuel" debate stem largely from the allocations of both food crops in supplying the food market, or dedicating it to biofuel production; and the assignment of land to either grow food market crops, or crops for biofuel production (Tuazon and Gnansounou, 2017). The creation of essentially two independent markets for crops (one for biofuels and one for food supply) has the potential to cause gross instability through biofuel growth incentivization, which could dramatically increase international food prices (Tuazon and Gnansounou, 2017). Rising food prices in the international market risks compromising adequate or less than adequate food stocks in both vulnerable underdeveloped and developing societies with low food security (German et al., 2011).

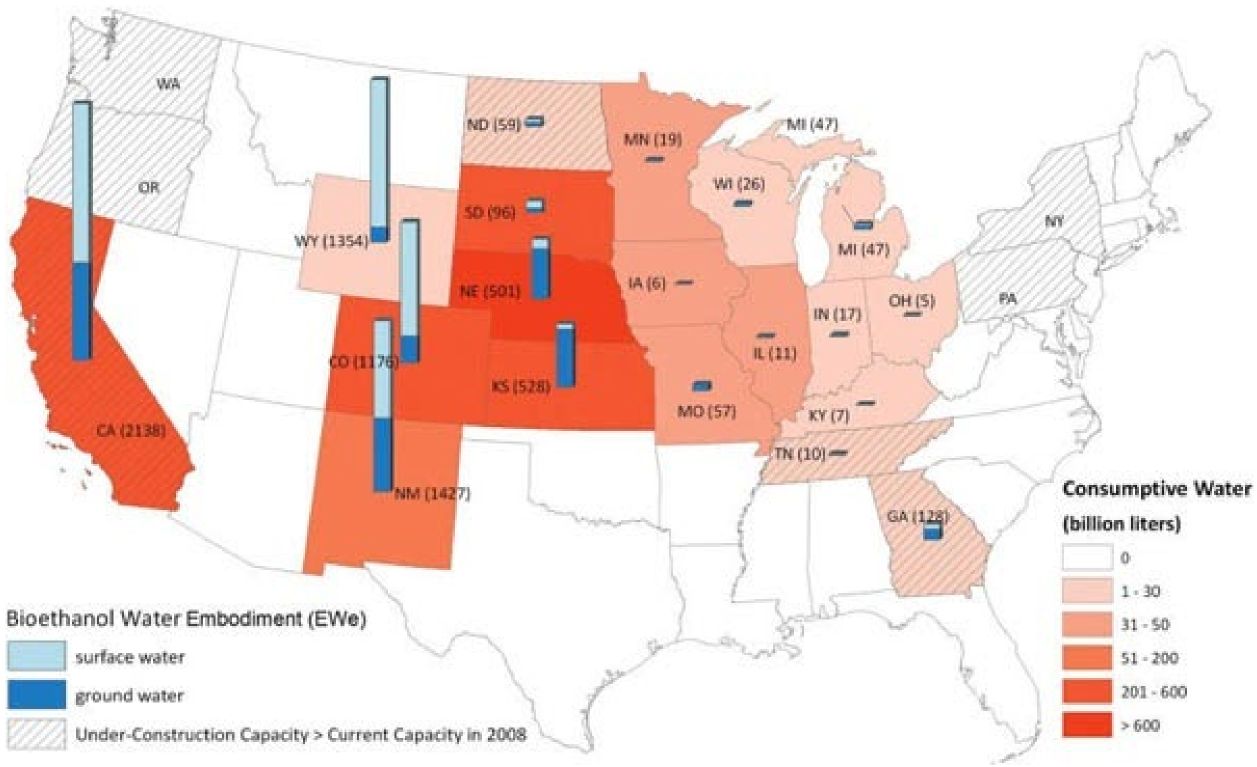

Figure 3. The above diagram represents the total water requirements for conservation of ethanol by state (United states) and irrigation. Additionally, the diagram depicts the total water used in ethanol production by state (Mckenna, 2009). Highlighting the large amounts of water consumed specifically for ethanol corn.

The 2008 food price crisis stands as a pertinent example for the ability of biofuel production to negatively affect regional food security. While not a primary conductor of the crisis, biofuel production certainly exacerbated the situation for vulnerable populations largely in West Africa, Latin America and South East Asia, as the United States (the world leader in maize production) dedicated 40% of maize production to ethanol fuel development (Timilsina and Zilberman, 2014). The popularisation of biofuels can also generate social tensions on a local scale as farmers within subsistent communities may be incentivized to shift their production, potentially severing the trust between producer and consumer if a balance between the needs of the community and biofuel production is not found (Tuazon and Gnansounou, 2017).

Naturally an increasing biofuel output has resulted in the rise of large scale land transactions meant to develop dedicated biofuel cropland whilst simultaneously displacing the customary livelihoods of the previous land users (German et al., 2011). Land transfer becomes heavily problematic in countries where largely informal land rights and "irregularities in practice" lead the customary land users to be vigorously manipulated by outside actors, essentially resulting in a system which awards great concessions to private investors. For example, in Malaysia customary land rights are only recognised through a formal title, households that have not undergone the lengthy and expensive titling process have no grounds to request any form of consent nor compensation in regard to their loss of livelihood (German et al. 2011). Regardless of any potential benefit in transitioning to biofuels, numerous case studies draw similar conclusions concerning its implementation on an international level. In most cases, effective implementation of biofuel production involves a just and ethical transition for land holders as well as relevant policy to guide resource use which may come into conflict with traditional food agriculture.

Conclusion

In conclusion, biofuels can be regarded as an environmentally friendly and sustainable alternative to traditional fossil fuels. Biofuels can be produced from a variety of feedstocks and have a range of uses. Implementing the use of biofuels can lessen a country's dependency on foreign imports of traditional oil, improve the economy and decrease carbon emissions. However, there are a number of hurdles to overcome before biofuels can be implemented and industrialized large-scale. The environmental, economic and production challenges must be taken into consideration. The cost to produce biofuels, the energy intensiveness of transporting them, and avoiding the market of crops used for fuel from infringing on the market of crops used for food.

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