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Biofuel Production Combatting Water Scarcity, Climate Change, and Natural Resource Degradation

Introduction

Biofuels, such as ethanol or biodiesel are an alternative source for petroleum based fuel. These fuels we currently rely on are being depleted, are the major cause of increasing atmospheric CO_2 and thus increasing greenhouse gasses, seed international conflict, and fund the economies of known terrorist supporting governments in addition to known human rights violators. Currently, ethanol is viewed as the "cure" for fossil fuel dependence. Ethanol most commonly utilizes a fermentation approach with corn, sugar cane or cellulose as the carbon source. Sugar cane is currently the star crop of ethanol production worldwide with corn a close second.

Unfortunately, in many ways, the negatives of ethanol production outweigh the benefits. With current technology, even the crops with high sugar content are inefficient converters of plant/solar energy to chemical energy that can fuel machinery. Greenhouse gases are released at several points in the production of ethanol, including fertilizer and herbicide manufacture, machinery used to plant, harvest and transport crops, and most significantly during the fermentation and production of the ethanol itself as it requires heat produced by burning either natural gas or coal. Monoculture farming increases fertilizer and pesticide use and causes soil erosion and pollution. Another problem that is commonly overlooked is that food security is significantly challenged by ethanol production, especially in developing countries. Food crops are diverted from human or animal use to biofuel production. Natural habitats are also being consumed by the hunger for increased farmland. Decreased natural habitats, especially in rainforest areas will further cause climate change.

Corn is already the most heavily subsidized crop in the US so prices are currently very high for the US farmer, yet the supports, given directly to the farmers, make export prices very low, undercutting the crop prices in developing countries. This is exacerbated by the additional government investment in ethanol production. The subsistence farmer in countries were corn is a main crop are devastated by these price supports combined with problems such as little or no modern farm machinery or farming methods, unimproved seed, little access to irrigation, and thus very low yields (often less than 25% of US levels).

As the largest producer of greenhouse gases, a major obstacle to use of ethanol in the US is that it cannot be used in existing engines in large quantities. Either engines have to be modified or the ethanol blend must be further processed. The capital investment and lifestyle changes needed decreases the willingness to make the change in the US.

As opposed to ethanol, biodiesel is an environmentally friendlier fuel made from plant-based oils that are free of sulfur and aromatics when used. When produced, it uses significantly less energy than distilling corn into ethanol. Based on a 1998 study, Carbon dioxide (CO_2) emissions are decreased by 78% compared to petroleum diesel. Since diesel is the primary fuel used for machinery this can greatly impact pollution and release of greenhouse gases. Further, it can be used in existing diesel engines without any modifications, thus making transition much more economically feasible.

A remarkable alternative biofuel production method already exists, having been studied since the 1970's. Cultivating select species of algae has shown to be a solution to the biofuel problems by

harnessing the most primitive application of photosynthesis. The two key ingredients needed for algae production are sun and CO2 and it can be accomplished on non-arable desert land and in a highly polluted (high CO2) environment. Mexico supplies an ideal environment for the application of algae-based biofuel production. In addition to wide swathes of unusable desert land, intense sunshine, some of the most polluted cities on the planet, there is a well-trained population of agricultural workers.

Proposal

The idea for using algae for biofuel production came about as a secondary, unexpected outcome of US Department of Energy research to decrease pollution near coal factories. CO_2 emissions were simply bubbled through shallow algae pools. This otherwise dangerous "greenhouse gas" was turned into a benefit that fed the algae. They next found that some species of algae contain oil content of greater than 50 percent and can be manufactured into biodiesel. The algae beds were built as shallow pools in desert areas, making it exceptionally easy to replicate. It was further found that algae can be fed on waste streams; an efficient way to utilize the manure from livestock production or human waste. Also, after the oil content is processed from the algae, nitrogen and phosphorous can be recovered and made into a high-quality fertilizer. Algae consume CO_2 as their carbon source for photosynthesis so can decrease climate change.

Compared to ethanol's annual yields of 300 gallons per acre, biofuel derived from the simple growth method using shallow algae beds can annually yield 5000-10,000 gallons per acre. This comparison is further significant because ethanol crops are grown on arable farmland and algae can be propagated on unusable desert, marshlands or even in saltwater along shorelines. Using more high efficiency closed system vertical membranes to grow algae, it is possible to get 15,000 gallons of biodiesel per acre.

Two approaches to algae propagation include a simple open pool method and a more complex closed growth system that uses vertical membranes or tubelike bags. The pool method is created by using small shallow open circular pools that are shaped like a "racetrack." Water flow starts in one spot, encouraged by paddle wheels and nutrients and CO_2 fed into the water. The slow flow around the oval track eventually comes back around to where it started and the algae is filtered out of the water. The CO_2 is most commonly supplied adjacent to some type of coal powered plant and the nutrients can be recycled from waste stream. This can be applied in either fresh or saline water environments by selecting the algae strains. The open pool method is attractive mainly due to low cost and low technology use. Algae is exceptionally easy to grow and as can be observed in lakes and swimming pools, can actually be quite hard to stop once it gets started.

The second approach uses vertically suspended sheets or plastic tubes for growing the algae. Algae oil cultivation begins with a solar concentrating system to collect visible light to distribute in a photobioreactor. The use of plastic fiber optic bundles makes the transmission of the necessary light more efficient. The light is used to illuminate ten square meters of algae growth. A controlled environment optimizes production, so the carbon-dioxide, water, nutrients, and sunlight are given to the algae in an efficient manner and can still use power plant emissions and waste stream by-products. When the vertical sheets hold mature algae, they are washed down to the bottom of the bioreactor and are then pumped into a harvesting box. The larger of the algae are then harvested, while the smaller algae are pumped back through the pipes and back into the sheets to restart the process. The tubes work in a similar fashion with the water pumped out, algae filtered out and then refilled.

When harvested, the algae oil is processed with a small amount of methanol to create biodiesel. It is an efficient process with no hazardous by-products. The US is the top consumer of petroleum-based

fuels. Biodiesel used directly in unchanged existing diesel engines can decrease US consumption by 60 million gallons, a third of the petroleum-oil used. Then, over the next few decades, the transition to diesel engines can be made gradually to make biodiesel a viable replacement.

Problems such as global warming would actually be to the benefit of algae. The higher CO_2 concentration and intense sun increases algae growth rate. An initial investment would need to be made for education and basic tools to teach the pool production or a larger investment for the closed vertical systems. While the machinery and technology for algae production would need to be purchased, it would then last indefinitely. It is also a year-round crop, which would mean year-round profits for farmers.

There is a famous saying in Mexico, “Sin maiz, no hay pais” or “without corn, there is no country.” Corn is the foundation of life in Mexico, and has been for the past 10,000 years. Those intertwined the most are the rural subsistence farmers. Their livelihood and main source of food has been the cultivation of corn. Unfortunately, since the early 1990's, conditions surrounding the farming of corn have brought the subsistence farmer in Mexico to a crisis that is threatening their very existence.

Twenty-five million Mexican people, one quarter of the population, depend on agriculture as their main source of income, yet this represents only 5% of Mexico’s gross national product. Half of Mexico is cropland with 40% of the cropland held by small communal village/family farms, called *ejidos*. The idea was to give the peasants a livelihood, but unfortunately *ejidos* were tied to the land without giving them any way to improve upon their land because they are unable to sell, rent, or use the land as collateral. This led to low productivity because there was no opportunity for capital investment in machinery, improved farming methods or even to change crops.

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One in two Mexicans in rural areas lives in extreme poverty. In the southern states, 70 percent live in extreme poverty. The life of a subsistence farmer is centered on the availability of cultivating corn. In a family-owned farm, a traditional subsistence farmer tries to grow half the crop for sale and the other crop for the family. Ideally, all hands are engaged on the farm from sunrise to sunset. Women cook, clean, tend the children, and help with the cultivating all at once. They also hold the time-consuming job of grinding corn for each day’s meals. The main diet of the family consists of corn, black beans and home-grown vegetables supplemented by infrequent meat or fish. The main part of the meal is made up of stone-ground corn tortillas, the specialty of Mexico.

Education is free but most families of the rural poor cannot meet the costs of basic equipment such as uniforms and school supplies. Girls especially end up leaving school after their primary years. If farmers were able to produce a year-round crop, a constant source income would enable the purchase of the necessary supplies and increase the chances the children can go to school for a longer period of time.

Agricultural economic hardships increased as a result of the North America Free Trade Agreement (NAFTA), loss of price supports, and ever increasing gap of agricultural knowledge and equipment between the developing and developed world. NAFTA’s intention was to provide Mexico with a larger and easier to access market. Instead, the influx of cheap US corn decimated the maize subsistence farmers, the main crop grown. Mexico did not have the capital investment or knowledge to take advantage of the open market. NAFTA hit them hard; prices fell so, in effect, they could not get acquainted with new ways or ideas. It teased the farmers with an open market that they had no viable access to. And since farmers are unable to compete in the free trade market, it is not uncommon for them to abandon their land and move to the city where they’ll struggle to find end-bit jobs.

Government support faded out when a program called Procampo was established to stabilize farmers in transitioning to the world market. Price supports, that had previously assisted farmers, were slowly easing. The previous *ejidos* system in place was reformed to give farmers the ability to sell or rent

the land. Expertise on this new policy was lacking and agriculture continued to decline. The need of machinery widened the gap between farmers in Mexico and the US. With NAFTA, maize prices fell by 45% in three years, and there was no extra money to use on equipment. In January of 2003, protective tariffs on imports were taken away completely and cheaper US products were imported into Mexico even more.

Food insecurity in Mexico is a direct result of NAFTA. Combined with the push for ethanol, very low corn prices make it impossible for the subsistence farmer to portion part of his crop for feeding his family and part for sale. Frequently, the farmer must sell his entire corn crop to make enough money to survive. Since corn is a dietary staple, they replace their whole grain white corn with purchased corn flour that is usually not a whole grain and is made from less nutritious yellow corn.

The lack of knowledge and equipment for modern farming debilitates Mexican subsistence farmers. With no way to compete with the industrial farming systems, they flounder and die out. In some cases, when Mexican farmers have attempted to reform, they were talked into trading their traditional corn varieties for "improved" hybrid corn seed. Unfortunately, the hybrid seed cannot be saved for the next year's crop, tying the subsistence farmer to purchasing seed every year and increases the need for fertilizer and pesticides. At times, accurate information was withheld about fertilizers, herbicides, and pesticides; which sickened their families when they were too liberal with the dosing, or ruined the crops for the opposite reason. These hardships illustrated to the government that the highest priority needs to be helping the 25 million subsistence farmers relying on agriculture as their main source of income.

Parts of Mexico (especially Mexico City) have been described by the United Nations as having the most dangerous air on the planet. The carbon dioxide levels are so bad that a haze hangs over the city. The situation has been attributed to a population boom, industrial growth, and aged inefficient vehicles. The geography also works against the pollution problem. The high altitude causes incomplete combustion in engines and, thus, higher emissions. The most serious pollutants are PM10, ozone, and carbon dioxide emissions. PM10 is a product of road construction, dust, forest fires, and incineration. Prolonged exposure to these pollutants can lead to premature death. Any effort by the government to curb pollution is hard to do because Mexico is an economically challenged developing country. There is no adequate source of revenue to draw money from and begin to fix the pollution problem. Other parts of Mexico are similarly bad.

Therefore, the focal problems in Mexico are the struggling subsistence farmers with the modern corn crisis and the widespread pollution contributing to climate change. Amazingly enough, both can be solved with the implementing of a new type of crop that has the oil to create biodiesel; algae. Natural resource degradation can be reversed by algae consumption of carbon dioxide and release of oxygen. Mexico is increasingly suffering from water scarcity due to climate change. With the propagation of algae, farming can be accomplished with water from waste streams. Close systems of algae production make maximum use of any water source. The water is re-used so the harvests can continually use the same water. Additionally, climate change will only improve algae yield as more heat and sun contribute to the photosynthetic process.

Mexico provides experienced agricultural workers and an ideal climate to implement algae farming. The members of one *eijido* can be trained to cultivate algae. Algae can grow anywhere the cell membranes are installed or pools set up. The challenge for Mexico is lack of capital investment for new equipment, farming techniques and training. Corporate and government interest in biofuel research and production can bring the funds to solve these problems.

Conclusion

There is no perfect alternative method to fuel production at this time. Biodiesel based algae, however, is close to covering all the essential needs of the economy, people, and environment. And will additionally solve the challenges of water scarcity, natural resource degradation, and reverse climate change. When processed in shallow pools, it is very inexpensive and cost efficient, while being very simple to implement. Algae production provides approximately twenty times the fuel production of ethanol per acre per year. Algae can be produced anywhere, and actually flourish in desert areas where non-arable land makes it almost impossible for any other crop to grow. Thus the people living in locations of desert and hot climates can raise algae. By these standards, Mexico fits the description of a developing country where subsistence farmers are in need of news ideas because the old ones are failing. The *ejidos* communal/family farms is the system currently in use in Mexico that can lend itself to algae farming. Food security is enhanced when the main food crop and cropland are not diverted to biofuel production, as is the case with ethanol. Overall, bringing algae-based biofuel production is all the pieces of a puzzle fitting together. It will help the subsistence farmers, the environment, and will solve petroleum-based fuel dependency.

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