Team Project Report:

Biofuels: Innovation Growth and Adoption in the United States

Course: ETM 510/610 Energy Technology Innovations

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Index

1. Introduction

Biofuels production has had several effects on the agriculture, land use, rural economics and also in environmental aspects. This is because in one way or another, some agricultural products have had their prize increased due to their high demand in the industrial sector, domestic sector, and the energy industry. For instance, the prize of corn has gone high because there has been a high demand for corn to be used in ethanol production. On the other hand, this situation has provided economic incentives for some producers to devote additional land to corn production (Gaffigan 2009). This means that there are potential effects of biofuels production in the future. The potential future effects of expanded biofuels production in the U.S also include production of new energy crops for advanced biofuels. It must be understood that these new crops may affect the production of other crops and livestock on agricultural land.

The increasing corn ethanol production has had mixed effects on land use, crop selection and livestock production. For instance, in 2007, increased corn prizes led farmers to devote more land for corn and less for soybeans. It is therefore necessary to formulate policies that will harmonize the production of energy and food in the same land. Production of biofuels must be encouraged in a controlled manner in order to reduce overdependence on fossil fuel and at the same time make sure that the acreage of land devoted for agricultural produce is not reduced to the advantage of biofuels production.

1.1 Problem statement

The overreliance on fossil fuel as the main source of energy has caused many problems currently. Fossil fuel has been associated with economic and environmental problems. The oil industry is always affected by politics of the OPEC members (Miller & Spoolman 2010). Thus, if one of the member countries is politically destabilized, oil prizes will shoot up thereby leading to inflation. Many countries that rely heavily on imported fossil fuel are usually the hardest hit. Environmental problems caused by the oil industry include pollution. It is important to note that fossil fuel combustion contributes to the increase in carbon dioxide levels. Carbon dioxide is a greenhouse gas. It contributes to global warming and depletion of the ozone layer. The current climate changes attest to these effects of carbon dioxide production by combustion of fossil

fuels. In addition, sulfur dioxide and carbon dioxide produced by combustion of fossil fuels in industries and motor vehicles, causes acid rain that corrodes man made structures. Mining of coal, for example, destroys huge areas of land. Thus, fossil fuel also contributes to destruction of the natural landscape.

For these reasons, alternatives of fossil fuels have to be explored. Among the most effective alternatives is biofuels. Biofuels are used to serve similar purpose as fossil fuel. In fact, they are more advantageous to use because they cause minimum environmental pollution and are quite desirable for sustainable economic growth. Biofuels can be produced anywhere and a country need not source the raw materials from the international market. Biofuels do not require mining, and therefore does not destroy wide areas of land. These are the reasons that prompted a comprehensive study of biofuels and their potential in the United States.

1.2 What is Biofuels?

Biofuels are various types of fuels that are sourced in one way or another from biomass. Taking into consideration that fossil fuel is also biological in nature; it is much difficult to specifically distinguish biofuels from fossil fuel. However, one of the ways by which biofuels can be distinguished from fossil fuels is that biofuels do not add to the stock of carbon dioxide in the atmospheric reservoir. This is because biofuels give up the same amount of carbon they removed from the atmosphere. This suggests that biofuels must be Carbon dioxide neutral.

There are many kinds of biofuels that are being produced currently. They include vegetable oils, biodiesel, bioalcohols, ethanol, biogas and syngas (Habmigern, 2003). It is important to note that biodiesel was the first alternative energy source to be known by the general public. This fuel can be used by conventional vehicles even without modifications done to the engines. It gains its popularity in contemporary energy industry due to its compatibility with the existing fuel engines technology. Biodiesel is produced from agricultural crops and sugar cane. It is also produced from biomass. Another source of biodiesel can also be vegetable oil.

Another kind of biofuel is biogas. Its chemical composition is actually similar to that of natural gas. This means that biogas can serve the same purpose as natural gas. They are produced from plants and animal wastes. Biomass is also another alternative energy source that is most

appropriate for small scale heating. It is made up of woody residue and straw. Bioalcohols such as ethanol are also used as biofuels. Ethanol can be a substitute for gasoline in petrol engines (Hacking, 1986). It can be added to petroleum at up to 20% (v/v) without modification to vehicle engines. This makes them viable for use in the energy industry since they are environment friendly and can sustain the economy pretty well.

2. Literature Review

2.1 Brief History of Biofuels

Tracing biofuels can actually back to a long time ago, when people burring woods to fire for cooking or heating use and later using biofuels for electricity when electricity was discovered. With time goes by, after fossil fuels shown into the market, here came the first gray period of biofuels. People were crazy about fossil fuels since they were cheap and more powerful. In other words, fossil fuels serve people much more continence compared with biofuels. As we known, certain events will change the world. This was exactly happened when the World War II started. Countries like Germany were in serious shortage of fuel due to high demands of military. People put their attention on biofuels again as it could be the alternative other than importing fuels outside. But this did not last long since the war was over. People enjoyed sufficient energy from fossil fuels in the peaceful world. A high demand of energy was eventually causing the fuel crisis in 1973, which consequently brought biofuels back to the world stage. Up till now, because of both the economic affect like oil prices increasing and environmental affect like climate changes, most governments encourage their countries to work on renewable energies also called clean energies to deal with these hot issues. With no doubt, biofuels, as one of the clean energies, is the popular developing and studying field. (Biofuel.org.uk)

2.2 History of Biofuels in US

In US, ethanol coming from corn is the more concerns than biodiesel even though biodiesel share is increasing during recent years. Ever since 1908, US started to use bioethanol as a fuel source. The National Energy Act was approved by the US Congress in 1978 regarding to a

federal tax exemption for gasoline containing 10% ethanol. The major driver behind is that the locally available bioethanol helps US decrease its needs of importing fuels due to the naturally geographical distribution of fossil fuels. Currently, based on Pelkmans' study, tax incentives, clean fuel standards including the RFG oxygen requirement, restrictions on MTBE and rising gasoline prices are the key driven in US's ethanol market. Biofuels consumption is estimated to represent around 2.5% of transport fuels on energy basis (3.6% by volume) in the US in 2012. (Pelkmans, 2005)

U.S. Energy Information Administration (EIA) summarized the motor fuels consumption during 2000 and 2005 period in Table 1. The consumption of gasoline in these five years still has the largest share, while ethanol's consumption is more than biodiesel in US. Figure 1 is the latest biorefinery locations in US updated on May 19th 2011 by Renewable Fuels Association (RFA). Biodiesel, on the other hand, first appeared in US as for the research use. Figure 2 shows the history of US biodiesel production from 2000 to 2008.

(million gallons per year)

	Gasoline	*Ethanol*	*Percent of gasoline pool*
2000	*128,662*	*1,630*	*1.27*
2001	*129,312*	*1,770*	*1.37*
2002	*132,782*	*2,130*	*1.60*
2003	*134,089*	*2,800*	*2.09*
2004	*137,022*	*3,400*	*2.48*
2005	*136,949*	*3,904*	*2.85*
	Diesel	*Biodiesel*	*Percent of diesel fuel pool*
2000	*37,238*	—	—
2001	*38,155*	*9*	*0.02*
2002	*38,881*	*11*	*0.03*
2003	*40,856*	*18*	*0.04*
2004	*42,773*	*28*	*0.07*
2005	*43,180*	*91*	*0.21*

Table 1: U.S. motor fuels consumption, 2000-2005 (EIA)

Figure 1: Location of US ethanol production facilities (RFA 2011)

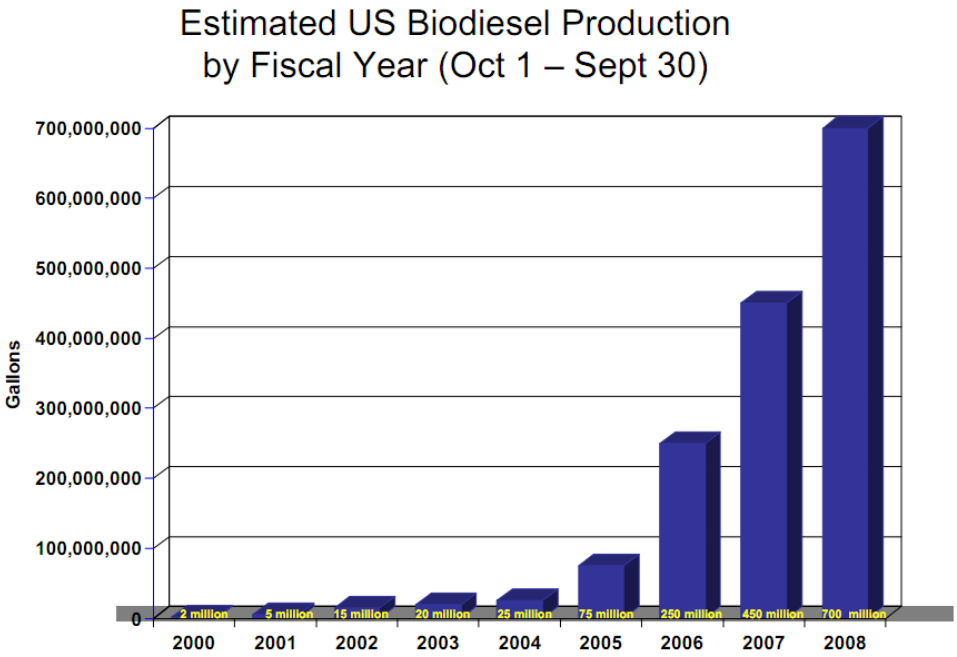

Figure 2: Evolution of US biodiesel production 2000-2008 (NBB)

2.3 Biofuel Application

The production of biofuel has tripled this past decade. This phenomenon is a result of a continuous rise in the prices of oil. When the main source of energy has become more expensive, people tend to look for other ways and means to supplement, or even replace, their energy source. Of course, this shift will only happen if the "newcomer" is cheaper than the original expensive choice. The chart below clearly demonstrates how the world interest in biofuel has become more evident than ever before (Coyle, 2007).

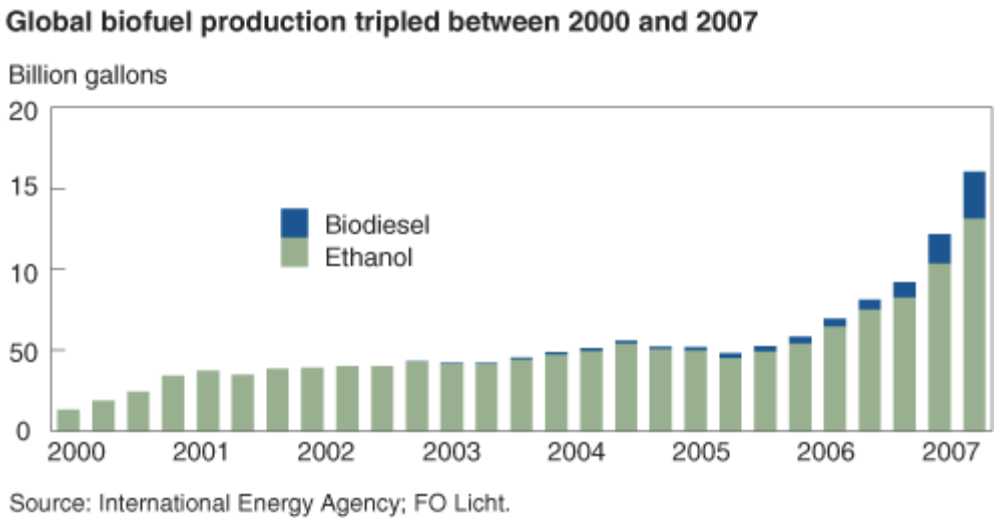

Figure 3: Global Biofuel Production Chart

To further dive into this rise in interest in biofuel, the graph below (Figure 4) shows the percentage of the world production of biofuel in 2007. It is clearly vivid that the United States and Brazil are the biggest biofuel producers in the world. The European Union ranks third place after Brazil and the Untied States. The rest of the world shares a total percentage less than 10%. What makes this chart interesting is the fact that very few countries are interested in pursuing the production of the energy source. Whereas, the rest of the world has not fully, or may even not, consider the option of biofuel production (Coyle, 2007).

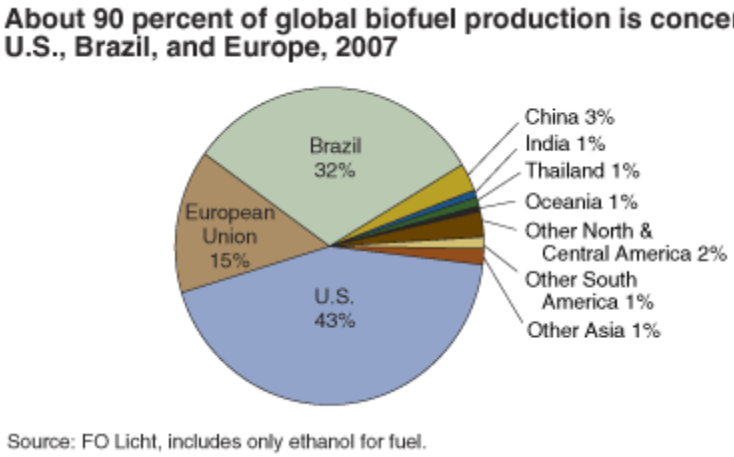

Figure 4

The production of biofuel is dependent on the availability and prices of feedstock. This feedstock could range from sugarcane, animal fat, vegetable oil, soybean, and other stocks. Therefore, if these elements are not available, the production of biofuel could not be possible. This means that only the countries that do possess or produce these feedstock are the ones that can actually consider producing biofuel. The chart below (Table 2) shows a number of countries and the feedstock they use to produce biofuel (Coyle, 2007).

Biofuel blending targets, selected countries					
Country	**Feedstocks**		**2007 production forecast (million gals.)**		**Blending targets**
	Ethanol	Biodiesel	Ethanol	Biodiesel	
Brazil	sugarcane, soybeans, palm oil	castor seed	4,966.50	64.1	25 percent blending ratio of ethanol with gasoline (E25) in 2007; 2 percent blend of biodiesel with diesel (B2) in early 2008, 5 percent by 2013.
Canada	corn, wheat, straw	animal fat, vegetable oils	264.2	25.4	5 percent ethanol content in gasoline by 2010; 2 percent biodiesel in diesel by 2012.
China	corn, wheat, cassava, sweet sorghum	used and imported vegetable oils, jatropha	422.7	29.9	Five provinces use 10 percent ethanol blend with gasoline; five more provinces targeted for expanded use.
EU	wheat, other grains, sugar beets, wine, alcohol	rapeseed, sunflower, soybeans	608.4	1,731.90	5.75 percent biofuel share of transportation fuel by 2010, 10 percent by 2020.
India	molasses, sugarcane	jatropha, imported palm oil	105.7	12	10 percent blending of ethanol in gasoline by late 2008, 5 percent biodiesel blend by 2012.
Indonesia	sugarcane, cassava	palm oil, jatropha	--	107.7	10 percent biofuel by 2010.

Malaysia	none	palm oil	--	86.8	5 percent biodiesel blend used in public vehicles; government plans to mandate B5 in diesel-consuming vehicles and in industry in the near future.
Thailand	molasses, cassava, sugarcane	palm oil, used vegetable oil	79.3	68.8	Plans call for E10 consumption to double by 2011 through use of price incentives; palm oil production will be increased to replace 10 percent of total diesel demand by 2012.
United States	primarily corn	soybeans, other oilseeds, animal fats, recycled fats and oil	6,498.70	444.5	Use of 7.5 billion gallons of biofuels by 2012; proposals to raise renewable fuel standard to 36 billion gallons (mostly from corn and cellulose) by 2022.

Source: United States Department of Agriculture (USDA)

Table 2

3. Technology Innovation Concept

Biomass is collected from the farms and transported to the processing plant. It is crushed and hydrolyzed. The crushed mash is heated with steam and fermented for about 3 days. This slurry is then filtered and distilled to a highest degree and collected in a steel tank for cooling. Both wet milling and dry milling methods are highly popular in the United States. The fuel ethanol in the US comes from the Biomass of Sugarcane and Corn (see Figure 5)

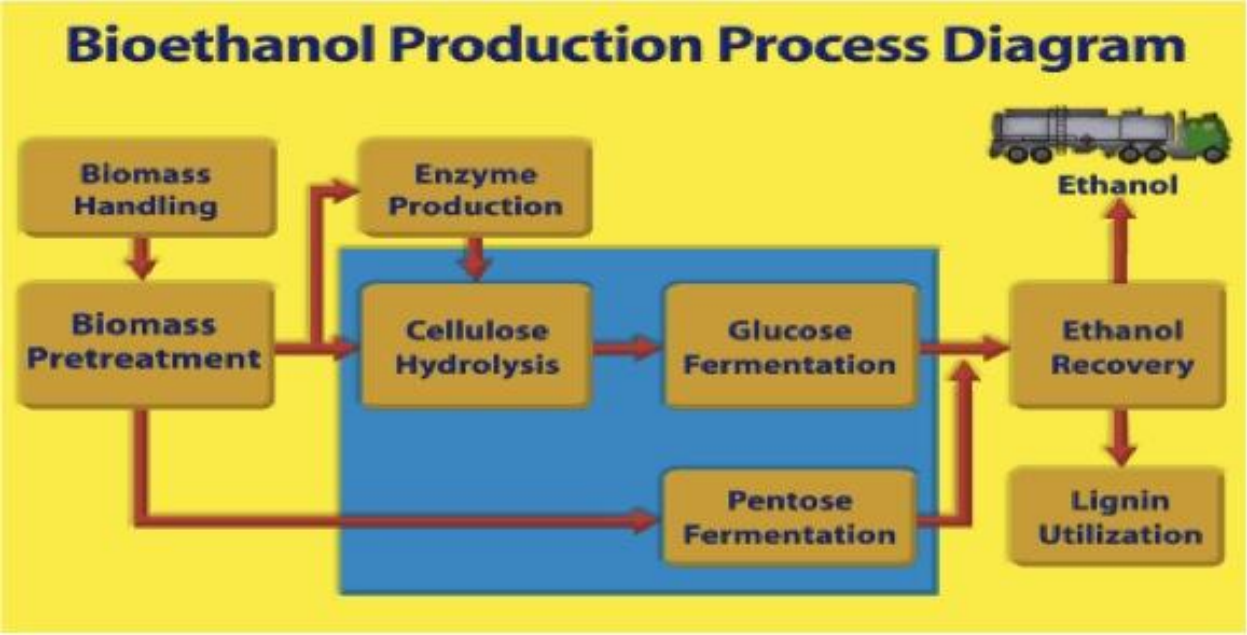

Figure 5

4. Methodology

The existing technology to manufacture Biofuels is not a recent invention. The recent surge in Biofuels is the result of increasing application of Ethanol as a supplementary fuel. The distillation technology is very mature and well understood and we are capable of manufacturing the purest fuel Ethanol for commercial use.

The challenge in this sphere lies in the fact that additional infrastructure needs to be in place for extensive use of Biofuels. The way out of this sticky situation is to be able to blend Biofuels into currently consumed fossil fuels. This is a two way approach which supplements foreign oil by increasing the ultimate product available as well as by passing the requirements to build a new infrastructure.

We intend to study the current situation of the Biofuel industry as well as forecast and foresee the adoption of Biofuels. From the existing data, we will forecast the growth of the industry and will try to create a frame work for the adoption of Biofuels on a nationwide scale.

To specifically study the subject in detail, we will be using our knowledge about Technology Acquisition and Assessment, Technology Forecasting, and Management of Engineering and Technology. We will also be using Dr. Fred Betz's Managing Technology "Innovation" as a basis of studying innovation in this industry.

After forecasting, we will study the impact of Biofuels from a technology organizational and personal perspective (T.O.P analysis) based on Dr. Harold A. Linstone's Decision Making for Technology Executives.

In this paper we have collected data for the Biofuels industry. After the data was collected, a technology analysis and data analysis were done to determine whether this technology should be used. By studying the current situation and looking at the industry growth, a technology forecasting methodology was applied to see if this technology is going to grow in a way that it can be adopted nationwide. We have done a T.O.P analysis of the impact of this technology assuming the forecast will be true (see Figure 6)

T.O.P Analysis:

This analysis is crucial for an engineering manager as it displays vividly the various real world perspectives an engineering manager has to consider. The three major perspectives that affect and determine the future of the technology are the technology itself, the technology organization, and the people that it influences (see Figure 7)

- Technology perspective – reliability, the "green" factor, ease of adoption and ease of operation, as well as many other technical aspects.

- Organizational perspective – the impact of the technology in its parent organization and various organizational aspects.
- Personal perspective - this is the “people” factor, all the stake holders that get influenced are studied while keeping in mind their personal ideology.

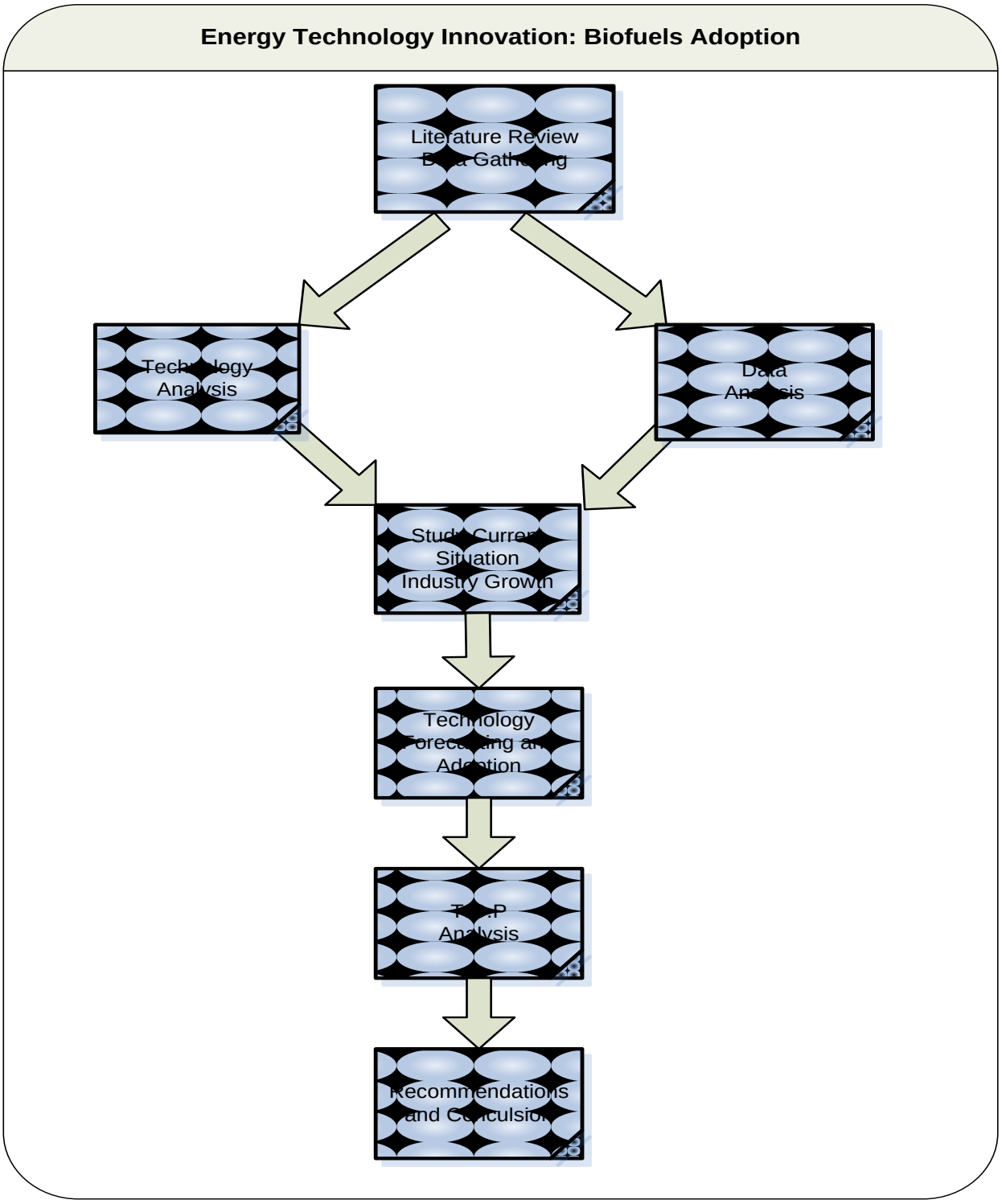
Energy Technology Innovation: Biofuels Adoption
Literature Review
Data Gathering
Technology Analysis
Data Analysis
Study Current Situation Industry Growth
Technology Forecasting and Adoption
T.O.P Analysis
Recommendations and Conclusion

Figure 6

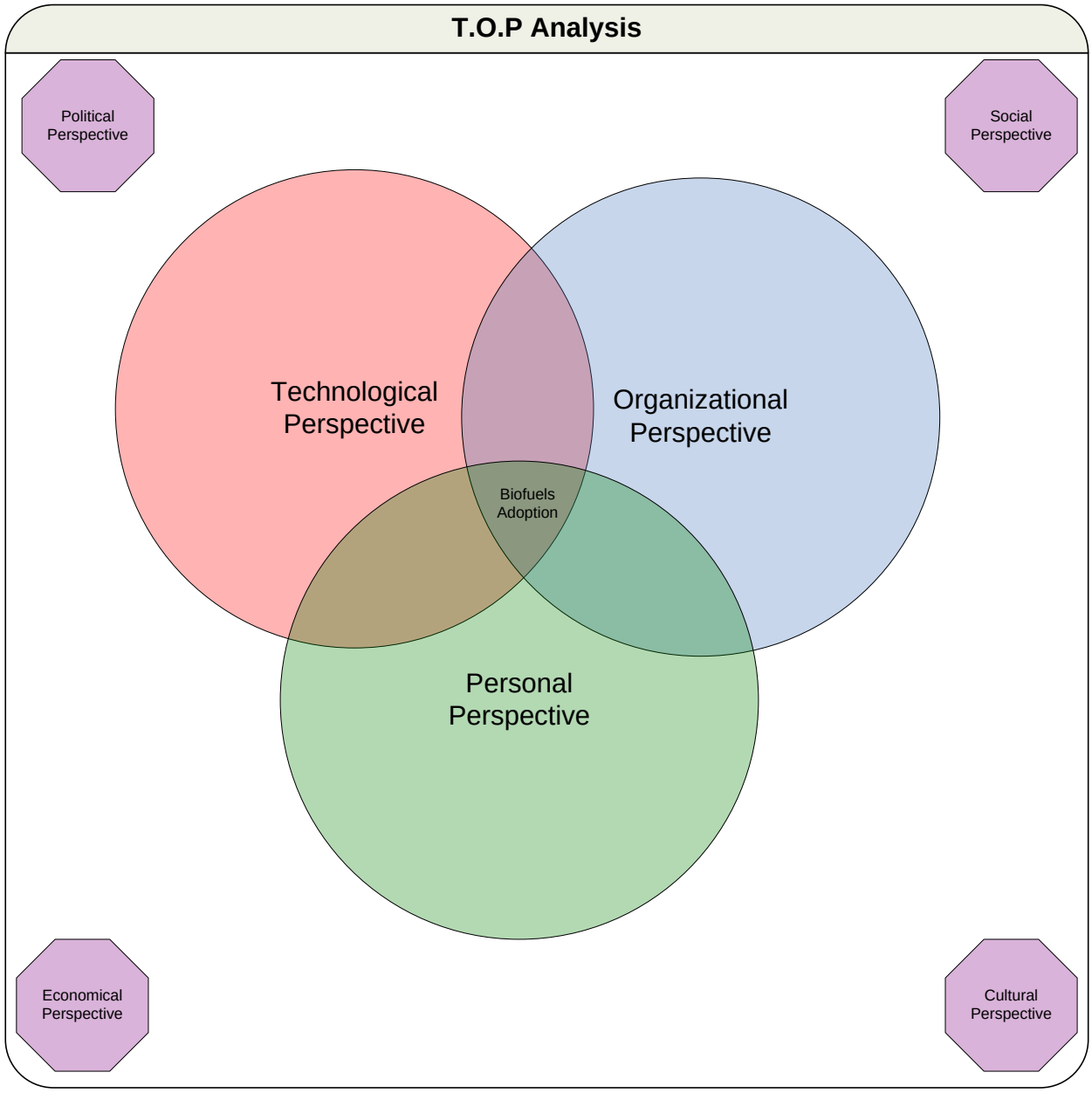
T.O.P Analysis
Political Perspective
Social Perspective
Technological Perspective
Organizational Perspective
Biofuels Adoption
Personal Perspective
Economical Perspective
Cultural Perspective

Figure 7

5. Current Capabilities

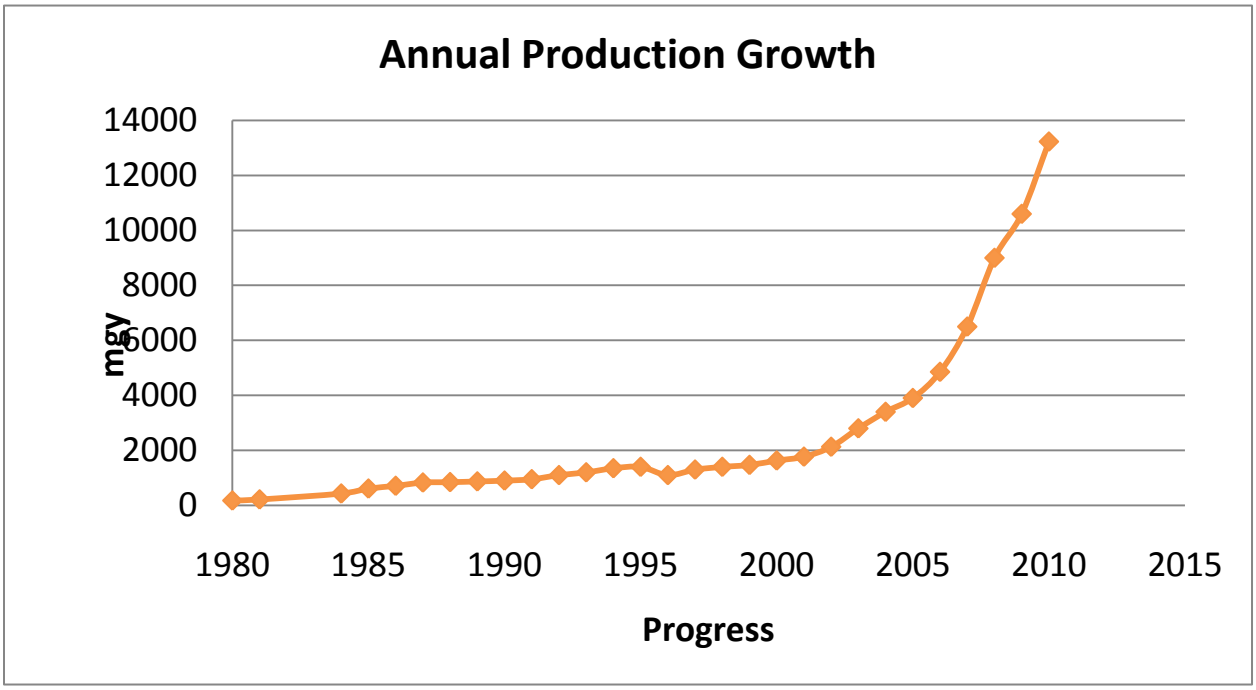

Figure 8

Federal Tax Credits for Ethanol and Biodiesel

Biofuel	Description	Incentive[a]	Credit per Gallon (Dollars)	Tax Expenditures in Fiscal Year 2009[b] (Millions of dollars)	Expiration Date
Ethanol	Alcohol fuel produced from feedstocks (raw materials) containing plentiful natural sugars or starches that can be converted to sugars. Commercial production in the United States uses kernel corn as a feedstock.	A credit for ethanol (regardless of the feedstock) blended with gasoline for sale or use	0.45	5,160[c]	Dec. 31, 2010
Cellulosic Ethanol	Etharol produced from feedstocks such as corn stover (the leaves and stalks of corn plants), switchgrass (a tall North American grass used for hay and forage), wood chips, and plant wastes. In contrast to corn ethanol, the fermentable sugars necessary to produce etharol are provided by materials in the walls of the plants' cells.	A credit for cellulosic ethanol blended with gasoline for sale or use	1.01[d]	50[e]	Dec. 31, 2012
Biodiesel	Diesel fuel made from virgin agricultural products (such as soybean oil and animal fats) or recycled agricultural oils (such as tallow)	A credit for producing biodiesel	1.00	840[f]	Dec. 31, 2009[g]

Source: Congressional Budget Office.

Table 3

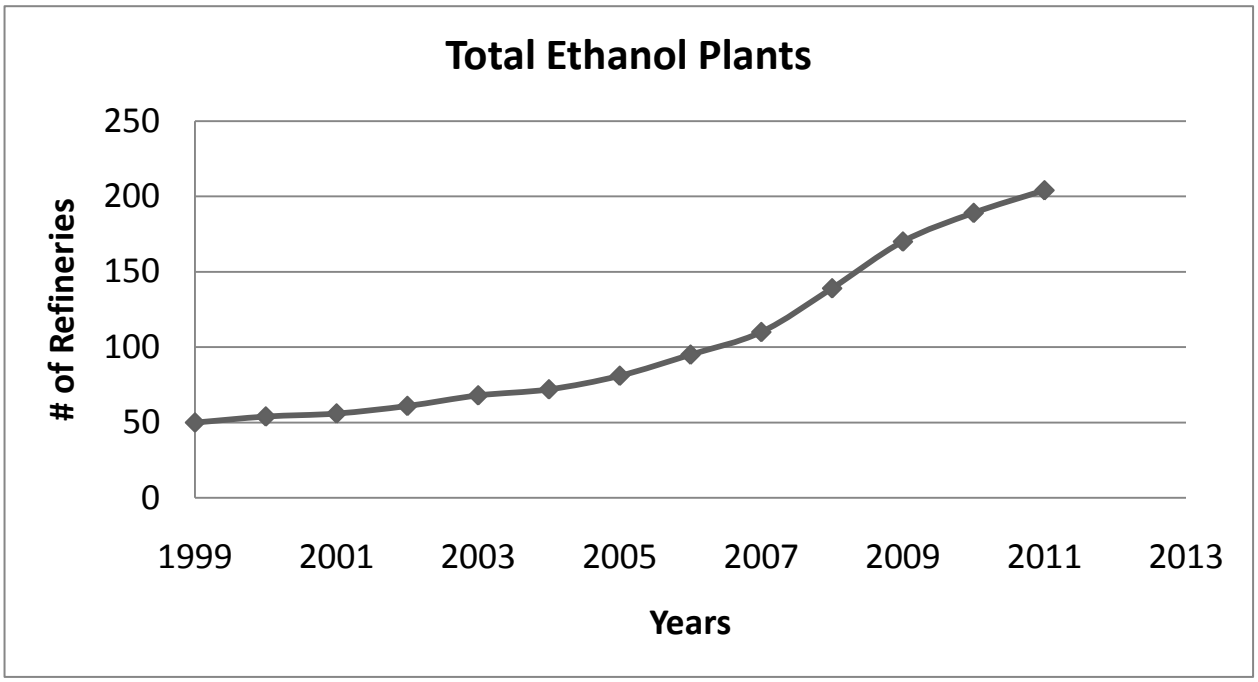

Figure 9

During the decade of the first oil crisis (1970's – 1980's) attention was brought upon the importance of indigenous sources for supplementing national fuel demand. It was after this oil shock that government funding started flowing in the direction of research and development for Biofuels. Being historically and agrarian country United States was naturally inclined to follow this path. This direction made economic and ethical sense because of the extensively available Biomass and agricultural waste, combined with existing facilities for processing sugar and distilling edible alcohol.

The inherent chemical properties of Ethanol make it a natural choice as the best blender's fuel for use with current petroleum fuels. Ethanol in its pure form can also be used as a standalone internal combustion engine fuel oil. Not only can Ethanol be used as a motor fuel, but it can also supplement industrial boiler fuels, power plant fuels, as well as agricultural equipments' fuel. An average large American farm consumes 44,000 gallons of fossil fuel annually. This itself is a huge challenge for the country of the size of United States.

Technology in its behavior has been "incentive" and "R&D dependent". Therefore, the government benefits and tax incentives are intended to push Biofuels as the pillar for domestic energy independence.

This is evident from the Figure 9 as we can observe the steady rise in the number of Bio-refineries since 1999. Not only have we seen a steady increase in the number of manufacturing facilities, but we also observe the rise in larger plants and increase in MGY (see Figure 8).

The Renewable Fuels Association mentions that the United States currently has 204 Bio-refineries running at a 97% efficiency and producing 13824 mgy from the installed capacity of 14295 mgy. Within the next 2 years, we will also see an addition of 673 mgy.

The recent oil shock forces energy intellectuals to think and rethink their policies and methods to approach the "oil problem" from a multiple perspective approach. A rejig of the existing bureaucracy is a must to reshape the American oil consumer and his/her ignorant attitude. In the last five years, we have seen more evidence of the government offering guaranteed finance through the federal loan guarantee program. This and other benefits will surely give a boost to the number of Bio-refineries in the future. Table 3 shows us the federal incentives currently available.

6. Forecasting and Adoption

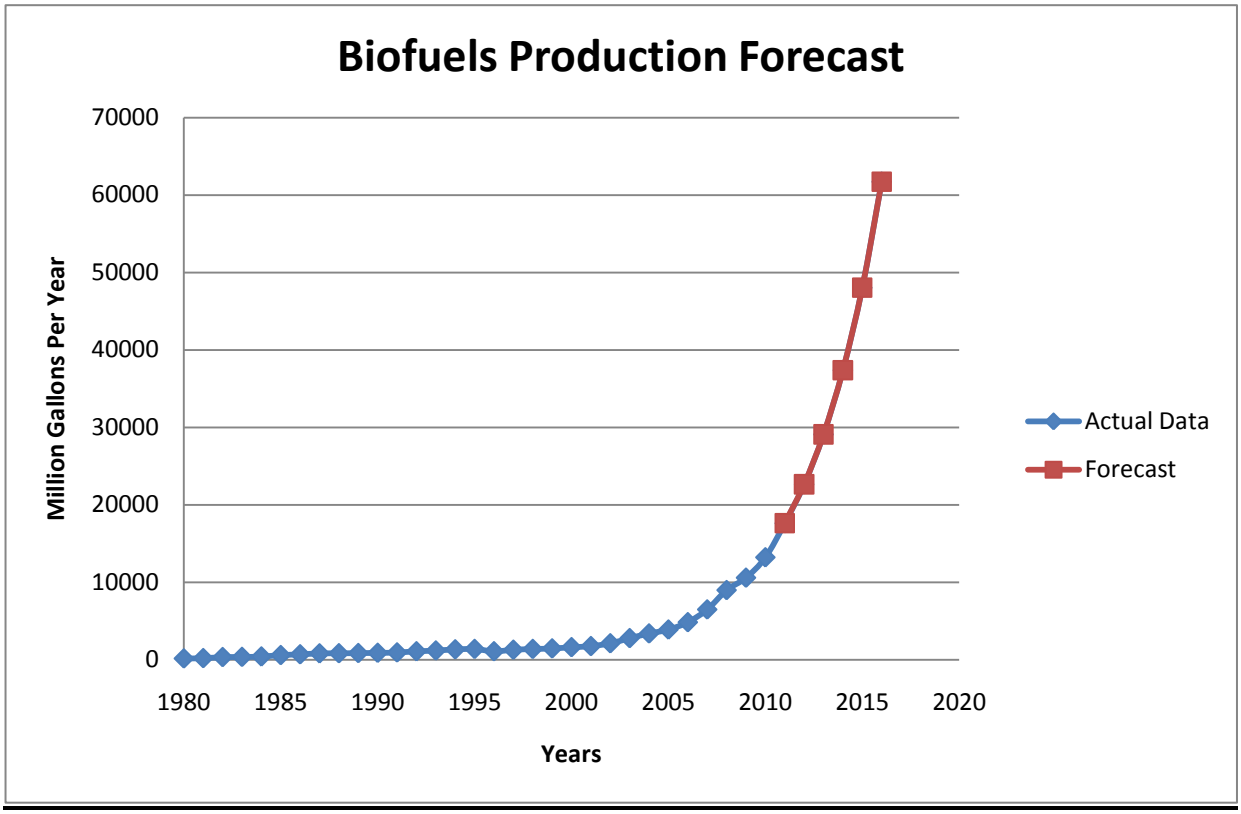

Figure 10

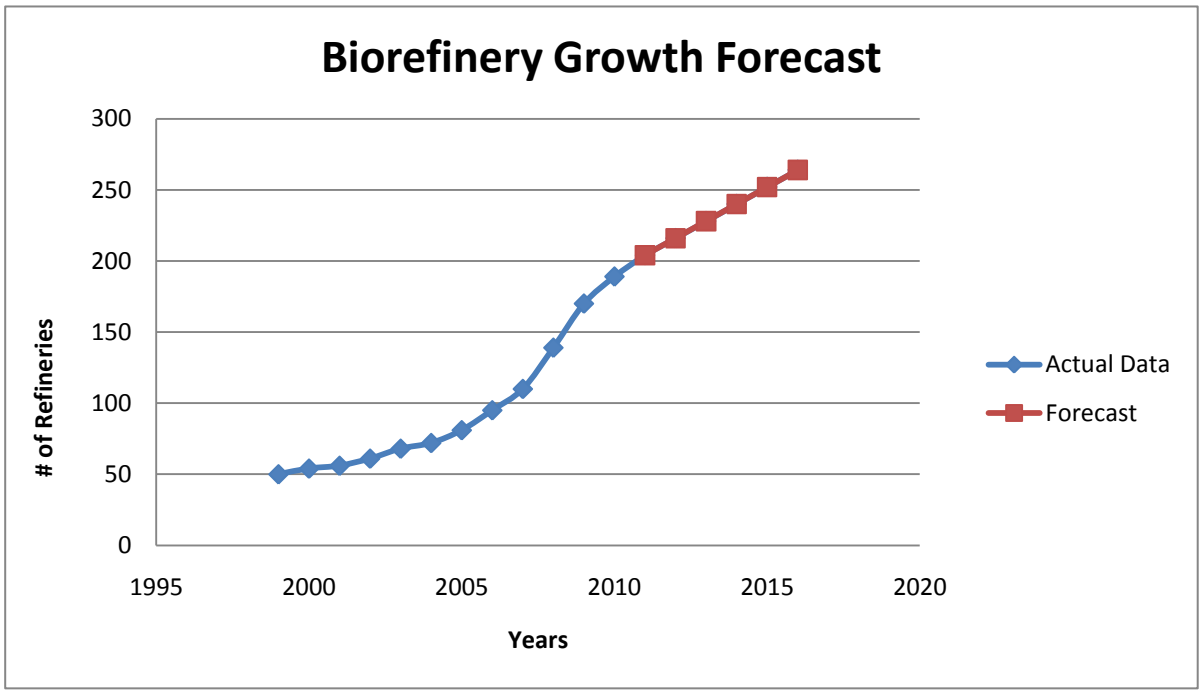

Figure 11

Based on the data from the National Renewable Energy Laboratory and Renewable Fuels Association, Figure 10 and Figure 11 forecast the future behavior of the Biofuel industry. Figure 11 shows us the forecasted increase in the number of the Bio-refineries facilties into the next decade. From the forecast we can foresee that by 2016 the number of Bio-refineries will increase from the existing 204 to 264. At the same time, this increase will be coupled with a steady increase in production which can be approximated at about 61723 mgy which is a five fold increase compared to the current capacity.

This kind of forecast shows us that if we cannot be completely foreign oil independent we can at least supplement indigenous resources to a substantial degree.

7. T.O.P Analysis

	Technological	Organizational	Personal
Cost	• Existing distilleries can be used • Up to 80% of funding for expansion and construction of new refineries is provided by the Federal and State government interest free • Has a 12 to 15 years return on investment (ROI).	• Provides supplementary income to sugar producers and distillers in an already sick industry. • One of the few energy sources that receives substantial Federal funding (reason for most sugar manufacturers to diversify) • Waste that was a problem of disposal has been turned into an opportunity to make revenues	• Compensation to small and medium sized sugar can and corn farmers per acre • Has created substantial number of jobs in the chemical engineering field • Can assist in strengthening the local economy (agrarian)
Capacity and Consumption	• Refineries for Biomass are being constructed with the largest capacities and tank farms • a 15 to 20 percent annual increase in capacity and production has been consistently observed for the last 20 years • 100% of Biofuel produced is consumed for blending with fossil fuels supplementing the gasoline by 14,000 mgy	• Economies of scale can be used to leverage cost versus benefit. • Larger capacities provide continuous production process • The guaranteed consumption of Biofuels (for blending) makes the industry commercially viable throughout the year	• Guarantees organizational growth • Supplementary fuel is available for use as boiler fuel and tractor fuel in remotely located farming communities

Benefit	• Mature technology with 100% purity has been developed and used on a commercial scale • There are currently no technology unknowns • Biofuels are 100% sulfur free	• Federally funded Bio-refineries are eligible for Kyoto protocol • Waste converted to revenue converted to a diversified company	• Biofuels do not go through price crisis as they are independent of import • Can contribute to the green way of life
Extent of Supplement to Fossil Fuels	• It is agreed that no Biofuel production currently can provide 100% fuel nationwide at the current consumption levels • Biofuel production can substantially supplement up to 15% through blending • The technology is weather and location independent	• Can be used as regional fuel supply source (example: tractors, boiler powered generators)	• Slowly the percentage of blending can be increased
Gaps	• Requires highly skill engineers to control and produce consistently pure fuels • Construction and commissioning of a plant is between 2-3 years • Volatility has been a technical challenge for few decades	• Most corporations are not culturally equipped to diversify • Resource and chemical engineering knowledge is limited • Ultimate production depends upon the size of the crop	• Blended fuel has been identified as a cause for knocking in cars • Lower quality blending shortness the life of the vehicle
Technology	• Mature • Reliable • Commercially available for all Bio-feeds • Plant life is 40-45 years • Complete automation available	• License fees for technology licensing is reimbursed by the Federal government • Ready templates for all scales and sizes are available	• Generates tremendous smell up to 1 miles radius • Biofuel distillation is an extremely explosive and noisy process

Table 4

8. The Trimet Example

Portland Metropolitan Region public transport system is unique in many ways in the nation. The bus transport division has 660 buses. The entire fleet primarily runs on regular diesel. 288 of the 660 buses have been converted to run on Biodiesel and its blended varieties. These 288 buses consume 6 million GPY of regular diesel in addition to 330K GPY of Bio-diesel. This kind of a miniscule consumption and usage by a vehicle fleet has ironically made TRIMET the largest consumer of biodiesel in the country per year. Keeping the scale in mind, we can now see why biofuels are yet too far away from satiating the nations thirst for oil.

Blending cannot completely replace the fossil fuels, but can supplement domestic demand up to 20%, which is a big number and could inturn have an impact on making the local economy robust as well as saving on import debt.

We must also note that a substantial amount of electrical energy is required to convert biomass to bio fuel and then blend that bio fuel to regular fuel. This process in fact is a source of much dreaded carbon emissions. Biofuels storage and transportation facilities also run into millions of dollars, and ROI is on a very distant horizon for small scale projects. TRIMET has had to spend on an average of $200kpa more than what they would spend on regular fuel. The maintenance expenses on the vehicles have risen, and the supply of bio-fuel has been unreliable. Seeing this, we can note that further research in cost reduction as well as fuel disbursing infrastructure is required for actually making biofuels a substantial supplementary source of energy (Trimet.org)

9. Research Limitation

Though the overall environmental of biofuels adoptions are pleasant, we still need to be under caution. Despite of lots of researching on biofuels, it is still not quite familiar to the public, the industry requires lots of qualified engineers and the fact that vehicles damage and other environment impacts such as noise. Governmental support is desperately needed in conducting the necessary research for finding the best methods in harvesting, utilizing, and storing energy obtained from biofuels. Additionally, local governments are not able to catch up with the rapid growth the energy industry is experiencing. This is considered a hurdle because governmental

initiatives and level of familiarities with biofuel advancement should be at the same level as the current industry, if not better.

From the energy class, we know how unstable renewable energy market is, especially in US. For alternative fuels, biofuels is the not the only option. In our project, we only forecast the biofuels potential within 6 years. But the question is will biofuels be able to nail in the market even when the next generation starts? We learned that people are forgetful when they do not experience the pain to its upmost degree. We are uncertain about the biofuels future in US especially when the economy is getting better and better. Maybe for biofuels, the best sustainable way is to work with Asian countries.

10. Recommendation

Based on the T.O.P. analysis (see Table 4), we think biofuels adoption in United States is valuable. The adoption cost is not super high for the private sectors. The biofuels information is highly supported by the Federal and state government. From the environmental side, biofuels is able to solve the waste disposal problem and meets the requirements of clean energy to eliminate the GHG. Not only biofuels can contribute in creating job opportunities and related industry revenues, the nation benefits from local resources. With biofuels, they don't need to highly rely on importing fuels. According to our forecasting results, we believe that the production of biofuels in US will dramatically increase from 2010 until 2016 and the bio-refinery facilities keep increasing as well.

In addition to this, governments should provide support in additional biofuel research and exploration of its undiscovered capabilities and potential. Moreover, a campaign of increase end-user awareness of the importance of biofuel will help in seizing public opinion. Both of these steps together can result in a significant tangible impact on shifting governmental and public focus on investing and switching to biofuel.

11. Conclusion

Through our thorough analysis of T.O.P. and forecasting, it is clearly shown how important it is to pursue biofuel adoption in the United States. The data that we have used in the generation of these results are based on hypothetical assumptions of how we envision the future will look like based on historic data. Biofuel is one of the few energy resources that we have not fully utilized as civilizations and has a tremendous amount of potential to supply and generate enough energy to replace current methods of energy consumptions. The level of dependency on conventional oil resources is deeply imbedded with our societies; however, one must take initiatives in finding those other energy sources in order to supplement, or even be the sole provider to those, current demand.

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