A Cost and Benefit, Case Study Analysis of Biofuels Systems

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The Green Economics Group
1 Executive Summary

Our deliverables report will directly address and quantify the present and future economic benefit biofuels have on the US economy and other relevant international regions. Through quantitative and qualitative measures, the latter involving background research on the topic and relevant speaker/expert interviews, we hope to compile a cost-benefit analysis that comprise the key points and findings of our research. The conclusions of our cost-benefit analysis will be then factored into the recommendations section. This deliverable paper examines the potential of investments in biofuels, both 1st (1G) and 2nd (2G) generation, by focusing on two crucial aspects of the topic:

1. Socioeconomic Cost-Benefit Analysis
2. Applied Net Present Value (NPV) Model

We aim to conduct a cost-benefit analysis of implementing and running biofuel systems, factoring in initial setup and input costs, as well as capital and operational costs throughout the project’s lifetime. The use of biofuel has several benefits including cost savings from reduced pollution and additional revenue; however, new advances in 2G biofuels warrants an increased investment and attention in the area for the long term. We hypothesize that for developed nations, the switch to 2G generation biofuels is optimal; however, for a less developed country, the costs of infrastructure, initial setup, and input and other unique costs make a current investment in biofuels quite expensive. These nations are better off continuing their first generation biofuels program while gradually developing their capacity for 2nd generation biofuels, which can prove to be very profitable in the near future. Our final results indicate that 2G biofuels are generally profitable and desirable for developed countries. The potential cost-savings and revenue generation warrants an increased investment in 2G biofuels. An industry comparison also reveals that biofuels have higher revenues than agriculture, but that the biofuel industry, particularly 1G biofuels, can be relatively more expensive and adversely impact food supply. Investors and nations should consider that the payoffs for 2G biofuels could still be far in the future while technology and cost-effective processes are in the development stage. Still, developed nations should strongly consider increasing investments in biofuel production and technology for their expected future returns. In contrast, developing nation biofuels systems will run into negative returns due to the relatively high cost of operation, lower revenue, and other factors, such as high corruption. Until adequate cost-savings and efficient technology have been developed for biofuels, most developing nations should concentrate on investments in the agriculture industry for export markets and maintain their food supply. Larger developing countries with a history of working with biofuels should continue to invest in the industry to maximize any expected revenue returns, albeit with additional investments from the public and private sectors.

2 Introduction

Within the past decade, biofuels have become key research initiatives and investments for many states with implications on agricultural and developmental economics. Recent innovations in both first generation (1G) and second generation (2G) biofuels herald a long-term emphasis on energy sustainability and efficiency. This paper presents a methodology for the economic analysis of investment in different types of biofuel systems. Our paper aims to determine whether 1G and 2G biofuels would be a viable economic and financial investment for typical developed and developing nations, respectively. First, we will collate and analyze the empirical findings on the socioeconomic effects of biofuels to construct a cost-benefit analysis, focusing on US-based and international case studies. We will then analyze the energy and emissions potential of biofuels. Following the qualitative report, the team will explain and apply relevant figures and numbers to an updated NPV model to gauge the respective investments in 1G and 2G biofuels for a developed country (United States) and for less developed/developing countries (Brazil)—these countries have exhibited potential for biofuel investment in terms of research, land, and crop allocations. The model simulates the rate of return (in dollars), or net benefit, of a conventional investment in 1G generation biofuels and a new investment in
2G generation biofuels over a 15-year time frame. Relevant ratios and metrics given the resulting numbers will also be analyzed in context. We also hope to compare these model figures with that of a coal plant, and if these lands were used to grow regular food crops instead—what is the efficient economic investment? Finally, given this wealth of empirical and quantitative data, the team will construct general investment and policy recommendations with applications in policy and economics.

For the purposes of the model, the model will simulate costs and revenues of Ethanol versus Miscanthus/cellulosic ethanol for the biofuels comparison. We then compare these numbers with the amount of energy per gallon of gasoline and compare this with the price per gallon.

3 Socioeconomic Cost-benefit Analysis (Biofuels)

3.1 The Socioeconomic Impact of First Generation Biofuels

3.1.1 Domestic Impact of Biofuels in Current Consumption and Production

As of 2013, the first generation biofuels have enjoyed regular and assured growth. This trend has generally remained true thanks to the Energy Independence and Security Act of 2007 (EISA) Renewable Fuel Standard (RFS), which requires the blending of renewable fuels into traditional petroleum-based fuels. For first generation biofuels, they demonstrate a 20 reduction in lifecycle greenhouse gas (GHG) emissions compared to the baseline of the original fuel.\(^1\) As a result of this standard, biofuels, predominantly starch ethanol and biodiesel, have been increasingly introduced into fuels since 2005, when the standard was originally implemented as part of the 2005 Energy Policy Act.

Today, biodiesel production is an estimated 135 million gallons in December 2013 with a capacity of 2.2 billion gallons per year.\(^2\) Ethanol production is 1.2 billion gallons in December 2013 with a capacity of 13.852 billion gallons per year.\(^3\) This is a large increase from 2012, during which the nation experienced a month-to-month decline in biofuel production due to the drought afflicting many of the nation’s agricultural regions. With the ebbing of the drought in 2013, biofuel production resumed. Ethanol production averaged 925,000 bbl/day in 2014, while biodiesel production averaged 87,000 bbl/d.

![U.S. monthly biodiesel production 2011 - 2013](image)


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3.1.2 Projected Consumption and Production

Over the next several decades, biofuels experienced some growth, but remained a small portion of the US liquid fuel supply. According to the U.S. Energy Information Administration, biofuels will grow about 0.4 million barrels per day from 2011 to 2040, thanks to the RFS mandate. This growth rate could increase if the RFS was increased, though for the moment that seems unlikely. However, despite the mandate, overall biofuel growth will remain limited over time as a result of decreased gasoline consumption, according to a prediction from the EIA. This decline, down to 8.1 million barrels per day in 2022, will also cause biofuels to fall short of the EISA 2007 target. As a result, the mandate is not likely to cause any additional growth in biofuels in this half-century. After 2020, second generation biofuels will over take first generation biofuels and provide most of the industry's growth. Ethanol consumption is projected to decline to 14.9 billion gallons in 2040. Despite the decline, ethanol will continue to be the primary biofuel in the United States.

![Renewable Fuel Standard Volumes by Year](image)

Source: (U.S. Department of Energy, 2013)

3.1.3 International Impact of Biofuels in Current Consumption and Production

Internationally, biofuel production and consumption is dominated by the United States and Brazil. In 2011, the two represent 70% of global biofuel consumption and 74% of global production. Biofuels in the United States are dominated by corn-based ethanol, while those from Brazil are primarily sugar cane-based. Both fuel types have been growing in use and consumption in the past decade. Other countries contribute to global biofuel production and consumption as well, such as France, Germany, and China. France, Germany, and other countries favor biodiesel due to the large number of diesel vehicles in those countries. Meanwhile, China prefers to use fuel ethanol. However, in no country but the United States and Brazil do biofuels compose a significant portion of the country’s fuel or energy supplies.

3.1.4 Projected Consumption and Production

Mirroring current levels, biofuel consumption is projected remain rather low on global scale, even when both 1G and 2G biofuels are included. The total increase in renewable energy consumption, which includes biofuels, is only projected to be a meagre 4%, from 11% to 15% of global energy consumption by 2040. More specifically, transportation fuels, the primary category under which biofuels are included, are projected to

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growth 1.1% per year, or 38% overall, by 2040.\textsuperscript{6} Within transportation fuels, non-petroleum liquid fuels, a category predominantly composed of biofuels, will experience 3.7% annual growth until 2040 with most of the growth coming from biofuel production in the United States and Brazil. Overall, this growth, while it may seem impressive, is small, if not outright negligible, in the face of global energy growth. Total global energy consumption will experience 56% growth between 2010 and 2040, or an increase from 524 quadrillion British thermal units (Btu) to 820 quadrillion Btu. While this overall energy growth will primarily occur in developing countries, most of the biofuel growth, as previously mentioned, will occur in the US and Brazil which currently have the two most established biofuel industries.\textsuperscript{7} In the face of this staggering growth, the future of biofuels as a mainstream fuel, outside of the US and Brazil, looks doubtful.

3.1.5 Environmental Impact and Emissions

Despite its occasional proclamation as a “green” fuel, first-generation biofuels, primarily ethanol, are not without their own GHG emissions. While ethanol does produce fewer overall GHG emissions than gasoline, its production is still an energy intensive process with secondary effects. Based on a study by Oliveira, Vaughan, and Rykiel, corn-based ethanol requires 65.02 gigajoules (GJ) of energy per hectare (ha) and produces approximately 1236.72 kg per ha of carbon dioxide (CO\textsubscript{2}), while sugar cane-based ethanol requires 42.43 GJ/ha and produces 2268.26 kg/ha of CO\textsubscript{2} under the assumption of non-carbon neutral energy production.\textsuperscript{8} These emissions accumulate from agricultural production, crop cultivation, and ethanol processing. Once the ethanol is blended with gasoline, it results in carbon-savings of approximately 0.89 kg of CO\textsubscript{2} per gallon.\textsuperscript{9}

3.1.6 Secondary Effects

Beyond emissions, first generation biofuel production has many secondary effects. These effects include issues such as land usage, water use, loss of biodiversity, and air pollutants. Unlike fossil fuels, which are generally limited to geographically smaller areas, the production of biofuels requires large tracts of arable land for agricultural production, in addition to land for the physical conversion plants. As a result, it suffers from many of the same problems agriculture is typically guilty of. These problems include water diversion and pollution, nutrient-deprived land, and destruction of natural habitats. However, since biofuels can increase the demands on agricultural cultivation, these secondary effects can spread across a wider area as biofuel production grows.

3.2 Impact on Food Supplies

3.2.1 Price

Since 2000, global food prices have been increasing rapidly. This spike in prices eased in 2009–2011 due to the Great Recession, however, food prices have maintained their upward trajectory nonetheless. Typically, biofuels, production issues, policy decisions, and droughts in major producing countries are the typical reason cited for this price increase. Biofuels contribute to the growth in food prices through the expansion of demand, which drives the redirection of food production to non-consumption areas. This redirection in turn perpetuates the growth in overall food prices due to the higher prices biofuels net for foodstuffs. For instance, 70% of the growth in corn production was used for biofuel production.\textsuperscript{10} This domination of crop growth by biofuels is the primary reason for the rapid increase in food prices.

While estimates vary, biofuels have undoubtedly contributed to the growth of food prices. One estimate by the International Food Policy Research Institute indicates that biofuels may be responsible for 30% of weighted food price increases from 2001–2007.\textsuperscript{11} Continued growth in biofuels can be expected to continue to add to the growth in food prices. Corn, as the primary crop used for biofuels, have seen the greatest price increases. However, due to the nature of the international food market and the usage of other crops, such as sugarcane, for biofuels, prices for all major crops have increased. These price increases have affected


\textsuperscript{7}Specifically, Energy usage in non-OECD countries will increase by 90%, while it will only increase by 17% in OECD countries.

\textsuperscript{8}Oliveira et al. \textit{Ethanol as fuel: energy, carbon dioxide balances, and ecological footprint}. 2005


\textsuperscript{10}Mitchell. \textit{A Note on Rising Food Prices}. 2008

\textsuperscript{11}Rosegrant. \textit{Biofuels and grain prices: impacts and policy responses}. 2008
both developed and developing countries and have been seen throughout the world through their effect on populations worldwide.

3.2.2 Supply

Based on its agricultural capacity, the United States will never be capable of producing enough first-generation biofuels to meet all of its fuel and energy needs without compromising its, and other nations’, food supply. The US produces a huge quantity of food destined for both domestic and foreign consumption. As one of the world’s largest agricultural exporters, many other nations depend on our food supply. Biofuels, as previously discussed, impact the availability of this food supply and our export capability. Based on 2005 corn supply figures, it would take 14.9% of the US corn production to meet merely 1.72% of the domestic energy equivalent to gasoline. To achieve a significant long-term reduction in fossil fuel usage through first-generation biofuels alone would be impossible due to this asymmetric effect on the food supply. As will later be discussed, second generation biofuels may have greater potential to reduce fossil fuel usage while maintaining food supply.

In international locales, we expect largely similar results, particularly in smaller, more densely populated nations. Currently, Brazil, the other major biofuel producer, has a higher percentage of their fuel consumption provided by biofuels. However, as their population grows and becomes wealthier, we can expect this percentage to decrease as they run into similar agricultural supply problems. If the United States and Brazil, two of the world’s largest agricultural producers, currently experience such difficulties, we can reasonably predict that most other nations will experience similar obstacles.

3.3 1G vs 2G

In recent years, the socioeconomic and environmental sustainability of first generation biofuels (1G) has been called into question. The viability of 1G energy crops such as corn, grains, and sugar cane is uncertain, primarily because they compete with food crops, and may not even offer significant GHG emissions reduction. Although there is a tendency to consider sustainability issues regarding second-generation energy crops (2G) as distinct from those of 1G crops, there are important lessons to be learned from sustainability challenges posed by 1G crops. The major categories of lignocellulosic biofuel feedstocks (2G) are as follows: agricultural residues (corn stover, sugarcane bagasse, etc), forest residues, and herbaceous and woody energy crops, including perennial forage crops like miscanthus and switchgrass. According to a 2013 report by Mohr and Raman, issues that are commonly classified as either environmental, economic, or social are often times more complexly related to each other.

For example, if controversy surrounding the production of 1G biofuels can be attributed to conflict about food security then 2G biofuels may be seen as a sustainable responses that are distinct because they are not produced from feedstocks commonly used for food production. Mohr and Raman point out, however, that food security quickly becomes a relevant issue when non-food energy crops are grown on land that could potentially be valued in food production, or if biofuel production using agricultural residues can be linked to 1G feedstocks. Proponents of 2G biofuels also cite their ability to be grown on land that would otherwise be considered marginal in arability, but this land could possibly be utilised by the poor for subsistence.

Nonetheless, cellulosic energy crops are promising because of their environmental benefits. In a 2008 report published by Madhu Khanna, reduced soil erosion, sequestration of higher volumes of carbon in soil compared to conservation tillage methods used with row crops, and lower input requirements for energy, water, and agrochemicals per unit of biofuel produced are all listed as potential incentives for transitioning to 2G biofuels. Khanna notes that environmental benefits vary depending on the crop’s ability to sequester carbon into soil and energy input requirements, among other factors.

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12Hill et al. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. 2006
14Mohr and Raman. Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels. 2013
3.3.1 Costs of Production

Khanna’s report includes useful quantitative metrics to assess the economic viability of cellulosic biofuel energy crops. From a production standpoint, miscanthus can produce 742.45 gallons of ethanol per acre of land, which is nearly twice as much as corn (398.75 gal/acre, assuming average yield of 145 bushels per acre under normal corn-soybean rotation) and nearly three times as much as corn stover (165.04 gal/acre) and switchgrass (214.74 gal/acre). Production costs are a big impediment to large-scale implementation of 2G biofuels, and their market demand will depend primarily on their price competitiveness relative to corn ethanol and gasoline. At the time of the paper’s writing, costs of conversion for cellulosic fuels, at $1.46 per gallon, were roughly twice that of corn-based ethanol, at $0.78 per gallon. Cellulosic biofuels from corn stover and miscanthus were 24% and 29% more expensive than corn ethanol, respectively, and switchgrass biofuel is more than twice as expensive as corn ethanol.

3.3.2 Social Impact

According to a 2010 report published by the World Bank, a major advantage of using agricultural residue crops to produce biofuels is that they do not require additional land. Thus, they should have almost no direct impact on food prices. Availability of land is undoubtedly one of the key considerations in the discussion of future potential for biofuels. Biofuels produced from crop and forest residues have significantly less land requirements than dedicated energy crops, such as switchgrass and miscanthus, do. Job creation and regional income growth are also important factors to consider in assessing the viability of 2G biofuel production. According to a 2010 report published by the International Energy Agency, there is potential for job creating in the cultivation of feedstocks based from dedicated energy crops. If production is based on residue use, then existing farm labor can be utilized, thus prolonging employment past the harvest season. Feedstock cultivation and transport do not require skilled labor and thus sufficient workforce can be accounted for even in developing economies. The use of residues can also bring added revenue to the agricultural and forestry industries, with particular impact on local economies and rural development.

3.3.3 Greenhouse Gas Emissions

Life-cycle analysis is often used to estimate the potential for various biofuel feedstocks to reduce GHG emissions in comparison to gasoline. Khanna’s findings show that corn and corn stover can reduce emissions by 37% and 94%, respectively, in comparison to energy equivalent gasoline. Switchgrass and miscanthus, however, are carbon sinks, meaning that they serve as natural reservoirs which accumulate and store carbon-containing chemical compounds for indefinite periods of time. A more comprehensive table compiled by the World Bank shows the relative GHG emission mitigation properties of various biofuels (see below).

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Emission Reductions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane ethanol</td>
<td>65 – 105</td>
</tr>
<tr>
<td>Wheat ethanol</td>
<td>-5 – 90</td>
</tr>
<tr>
<td>Corn ethanol</td>
<td>-20 – 55</td>
</tr>
<tr>
<td>Sugarbeet ethanol</td>
<td>30 – 60</td>
</tr>
<tr>
<td>Lignocellulose ethanol</td>
<td>45 – 112</td>
</tr>
<tr>
<td>Rapeseed biodiesel</td>
<td>20 – 80</td>
</tr>
<tr>
<td>Palm oil biodiesel</td>
<td>30 – 75</td>
</tr>
<tr>
<td>Jatropha biodiesel</td>
<td>50 – 100</td>
</tr>
<tr>
<td>Lignocellulose diesel</td>
<td>5 – 120</td>
</tr>
</tbody>
</table>

Source: OECD (2008), WWF (2007), Wang et al. (2007) and Whitaker and Heath (2009) data. *Values are approximate, as some reports only reported results in graphical form. **Negative numbers mean increases in GHG emissions. †Includes forest residues, energy crops (such as short tree rotations (e.g., poplar), and switchgrass) and crop residues (e.g., corn stover). ‡Whitaker and Heath (2009), their base case resulted in 62% GHG emission reductions when compared to diesel. Previous studies by Ecofys BV (2008, commissioned by D1 Oils) and Prueksakorn and Ghiwale (2006) reported values within that range (70% and 77% respectively).
4 Financial and Economic Model Analysis

Net Present Value (NPV) can be computed as the average discounted net cash inflows minus the average discounted net cash outflows less the Setup costs in the first period and a “waste” variable. The NPV model is a good model to show the projected value of an investment from a variety of fixed costs over a period of time, which are discounted back to the present. In the context of this paper, the projected value of an investment in a biofuels plant can be modelled using NPV analysis to deduce whether the investment should go through or not based on revenues and costs. Future models that expand on our model can include stochastic components that consider the changes in input costs over time, with accompanying regression analysis. The NPV results for biofuels can be contrasted with the same values from other renewable energy sources.

A project is deemed economically feasible if the NPV value is greater than zero. An NPV value of 0 does not confer any benefit; however, this result would not be optimal in the context of this paper. Negative NPV values indicate that the project would incur a net loss and the investment should not proceed. The value of the NPV, or the output variable, will determine the economic viability of the proposed project or plant. For economic efficiency to be achieved, the option that generates the maximum NPV must be selected.

In applying this model, we hope to apply the findings to developed and developing countries, and determine whether it is better to continue investment in 1G biofuels or make the shift to 2G generation biofuels over a period of time. Our results will be extrapolated and generalized for the different types of countries.

4.1 General Assumptions

We assume the following for our model:

1. **15 years time period measure**: Most governing and private institutions make decisions based on the payback of investment over increments of time, at least equal to or greater than 10 years for research involving long-term energy and fuel projects\(^{19}\) (International Food and Agribusiness Management Review, 2013).

2. **An Interest/Discount rate of \(\sim 7\%\) over a period of 15 years**, as is assumed for most studies of this nature (International Food and Agribusiness Management Review, 2013).

3. **We also assume the salvage value of the project is zero**, and that the operating institution will opt to give any and all assets to a licensed developer for proper, environmentally-friendly disposal at the end of the project’s lifetime.

4. **We assume a fixed increasing demand for biofuels based on population and fuel consumption growth**, which allows us to produce a general picture of the feasibility of biofuels on a large scale and is based on government mandated consumption.

5. **We assume a fixed corporate tax rate of 35% in developed countries and a fixed rate of 34% in developing countries on profits**, which is incorporated in the computation of operating expenses of the plant\(^{20}\):
   - Taxes will only be calculated from Total Operating Profits after the 15th year and then smoothed or spread over the 15 years.
   - If Total Operating Profits are negative once the 15 year calculations are done, or there are losses that create a negative tax, no tax will be imposed for all years.
   - All taxes are considered to be deferred tax liabilities until the 15th year, where all the taxes are then added and paid.

6. **We depreciate PP&E using the Straight Line Method (SLN)**, also incorporated in the computation of operating expenses, for the 15 year life of PP&E.

7. **The capital budgeting analysis assumes a 0% equity or bond financing.**

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8. The model begins at year one; however, due to typical start-up and setup costs of a development project, profits may only be realized after year 3.

9. Assume adequate land expansion for expansion of biofuel production, which will enable the generalization of this model to multiple situations.

10. The model is scaled down to calculate the viability of a single value, which will allow us to multiply the result to estimate the national costs and benefits and generalize it to other situations.

11. 50,000 hectares worth of biomass is processed annually, in both the first and second generation biofuel production plants. 50,000 hectares is the size of the commercial plot\textsuperscript{21}.

12. Biofuel sale prices remain fixed, to illustrate a minimum growth floor for biofuels.

13. For most biofuels plants, such as 1G sugarcane, energy self-sufficiency in mechanical and electrical energy is attainable, especially during the processing season\textsuperscript{22}. Thus, utility costs for plant operation can be zero.

4.2 Model and Model Parameters

To gauge the economic and financial viability of both investments, we will utilize an NPV model that takes into account the present value of all cash inflows and outflows, taking into account the initial setup cost and a waste variable, as defined below:

\[
NPV = \sum_{n=1}^{15} \frac{NCI_n}{(1+i)^n} - \sum_{n=1}^{15} \frac{NCO_n}{(1+i)^n} - S_1 - \epsilon_n
\]

\(NCI\) or Net Cash Inflow = Revenues + Funds from Financing + Funds from Investing

\(NCO\) or Net Cash Outflow = Operating Costs

Where \(S_1\) represents the initial capital and setup costs at year 1 to begin the project, which includes PP&E, and where the waste variable \(\epsilon_n\) represents unique costs to the project at a time \(n\), such as corruption or dramatic fluctuations in key input prices. We expect that for developing countries, this \(\epsilon_n\) variable would be quite high due to the incidences of government payoffs and relatively high input prices given more expensive rates of technological/research development in biofuels.

\(Net\ Cash\ Inflows\) includes earned revenues from project and plant operations, such as projected proceeds from the sale of biofuels and their derivatives, as well as revenues from energy output. Investments, such FDI and Domestic funding for biofuels R&D, constitute funds from financing, and are not considered direct expenses to the plant.

\(Net\ Cash\ Outflows\) take into account Operating costs and Production costs plus Operating Expenses include both variable and fixed costs. Operating expenses are expenses incurred in an organization’s day-to-day activities. Operating expenses for this project will be focused on a fixed employee salary, taxes, insurance, Research and Development (R&D), feedstock costs, and depreciation, as well as overheads and maintenance. Part of the Operating Expenses would include administrative expenses. Operating Costs are added to any purchases of Plant, Property, and Equipment (PP&E).

4.3 Ratios and Multiples Based on the Model

We also hope to calculate a variety of ratios and/or multiples based on the findings of our model.

\[
\text{Return on Investment (ROI)} = \left( \frac{\text{Total Revenue}}{\text{Total Operating Cost}} \right) \times 100
\]


5 Model Calculations and Findings

Our cost calculations are based on the average estimated cost of a 100 ML plant expanded for a 200.362244 ML plant.

5.1 Developed Nation 2nd Generation Biofuels Cost Structure (CASE A)

5.1.1 Revenues

50,000 hectares of process biomass annually equals 123,552,691 acres. 123,552,691 acres multiplied by $1,200 per acre (estimated full-yield revenue) will equal $148,263,229.24.

5.1.2 Investments

We identified that for most developed nations, the public-private investments for biosystem plant would be around $81,500,000.

5.1.3 Depreciation

5.2 Developing Nation 2nd Generation Biofuels Cost Structure (CASE B)

5.2.1 Revenue

Revenue for 50,000 hectares is $111,682,521.9726 given the 50,000 hectares plant size, and multiplying the 52,930,105.2 gallons per year produced by our plant by $2.11 per gallon of cellulosic ethanol market price for these biofuels.

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23 Eisentraut. Sustainable Production of Second-Generation Biofuels: Potential and Perspectives in Major Economies and Developing Countries. 2010
24 Jennings, P. Commercial Scale Giant Miscanthus 2011
26 Biofuel Costs, Technologies, and Economics in APEC Economies. BBI Biofuels Canada. 2010
27 Theis K. DOE Challenge met- research advances cut costs to produce fuel from non-food plant sources. 2014
5.2.2 Investments

Financing and set-up costs of commercial second-generation biofuel plants is between $125–250 million, averaged out to $187.5 million which includes both domestic funding and foreign direct investment.

5.2.3 Total Plant Costs

We have 39.87 bushels of corn per metric ton, with the 2013 average corn yield at 153 bushels per acre. We know $2.11 per gallon of cellulosic ethanol production, and since we have 2.8 gallons of ethanol per bushel of corn and 50,000 hectares or 123,553 acres. Thus, total bushels equals 18,903,609 bushels or 52,930,105.2 gallons per year. The final result of our calculations is 200.362244 ML. The cost of a 2G biofuel plant on average is $375.6792075 million.

5.2.4 PP&E

PP&E is generally low in developing countries, though quality may be a concern. In this case, the build cost of an advanced PP&E in a developing country is approximately $22 million.

5.2.5 Depreciation

<table>
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<td>$110,866,667</td>
<td>$0</td>
</tr>
<tr>
<td>2027</td>
<td>$4,400,000</td>
<td>$19,066,667</td>
<td>$129,933,333</td>
<td>$0</td>
</tr>
<tr>
<td>2028</td>
<td>$2,933,333</td>
<td>$20,533,333</td>
<td>$150,466,667</td>
<td>$0</td>
</tr>
<tr>
<td>2029</td>
<td>$1,466,667</td>
<td>$22,000,000</td>
<td>$172,000,000</td>
<td>$0</td>
</tr>
</tbody>
</table>

5.3 Developed Nation 1st Generation Biofuels Cost Structure (CASE C)

5.3.1 Revenues

Annual Revenue is $122,717,298, where revenues come from Ethanol and Dried Distillers Grains with Solubles (DDGS).

5.3.2 PP&E

Plant, Property, and Equipment is estimated to be $67,510,000.

28 Sustainable production of second-generation biofuels potential and perspectives in major economies and developing countries. 2010
30 Biofuel Costs, Technologies, and Economics in APEC Economies. BBI Biofuels Canada. 2010
31 Biofuel Costs, Technologies, and Economics in APEC Economies. BBI Biofuels Canada. 2010
5.3.3 Investments

$81,500,000 public-private investment for a biosystem plant.\(^{32}\)

5.3.4 Depreciation

![Depreciation Schedule]

<table>
<thead>
<tr>
<th>Year</th>
<th>Book Value Year Start</th>
<th>Depreciation Expense</th>
<th>Accumulated Depreciation</th>
<th>Book Value Year End</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$67,510,000</td>
<td>$4,500,666.67</td>
<td>$4,500,666.67</td>
<td>$63,009,333</td>
</tr>
<tr>
<td>2016</td>
<td>$63,009,333</td>
<td>$4,500,666.67</td>
<td>$9,001,333</td>
<td>$58,508,667</td>
</tr>
<tr>
<td>2017</td>
<td>$58,508,667</td>
<td>$4,500,666.67</td>
<td>$13,502,000</td>
<td>$54,008,000</td>
</tr>
<tr>
<td>2018</td>
<td>$54,008,000</td>
<td>$4,500,666.67</td>
<td>$18,002,667</td>
<td>$49,507,333</td>
</tr>
<tr>
<td>2019</td>
<td>$49,507,333</td>
<td>$4,500,666.67</td>
<td>$22,503,333</td>
<td>$45,006,667</td>
</tr>
<tr>
<td>2020</td>
<td>$45,006,667</td>
<td>$4,500,666.67</td>
<td>$27,004,000</td>
<td>$40,506,000</td>
</tr>
<tr>
<td>2021</td>
<td>$40,506,000</td>
<td>$4,500,666.67</td>
<td>$31,504,667</td>
<td>$36,005,333</td>
</tr>
<tr>
<td>2022</td>
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<td>$4,500,666.67</td>
<td>$36,005,333</td>
<td>$31,504,667</td>
</tr>
<tr>
<td>2023</td>
<td>$31,504,667</td>
<td>$4,500,666.67</td>
<td>$40,506,000</td>
<td>$27,004,000</td>
</tr>
<tr>
<td>2024</td>
<td>$27,004,000</td>
<td>$4,500,666.67</td>
<td>$45,006,667</td>
<td>$21,503,333</td>
</tr>
<tr>
<td>2025</td>
<td>$22,503,333</td>
<td>$4,500,666.67</td>
<td>$49,507,333</td>
<td>$18,002,667</td>
</tr>
<tr>
<td>2026</td>
<td>$18,002,667</td>
<td>$4,500,666.67</td>
<td>$54,008,000</td>
<td>$13,502,000</td>
</tr>
<tr>
<td>2027</td>
<td>$13,502,000</td>
<td>$4,500,666.67</td>
<td>$58,508,667</td>
<td>$9,001,333</td>
</tr>
<tr>
<td>2028</td>
<td>$9,001,333</td>
<td>$4,500,666.67</td>
<td>$63,009,333</td>
<td>$4,500,667</td>
</tr>
<tr>
<td>2029</td>
<td>$4,500,667</td>
<td>$4,500,666.67</td>
<td>$67,510,000</td>
<td>$0</td>
</tr>
</tbody>
</table>

5.4 Developing Nation 1st Generation Biofuels Cost Structure (CASE D)

5.4.1 Revenue

Revenue for 1G biofuels amounts to $1,000 revenue per hectare, which is $50,000,000 of annual revenue.\(^{33}\)

5.4.2 PP&E

PP&E estimated costs are $56,275,326.\(^{34}\)

5.4.3 Investments

Financing and set-up costs of commercial second-generation biofuel plants is averaged to $187.5 million which includes both domestic funding and foreign direct investment.\(^{35}\)

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\(^{32}\) The Future is Renewable. The Renewable Bio-Energy Systems. 2007

\(^{33}\) Bachner, D. Sugar Cane. 2013

\(^{34}\) Biofuel Costs, Technologies, and Economics in APEC Economies. BBI Biofuels Canada. 2010

\(^{35}\) Sustainable production of second-generation biofuels potential and perspectives in major economies and developing countries. 2010
5.4.4 Depreciation

6 Recommendations

As stated in the beginning of this analysis, our ultimate goal was to establish the present viability of first and second generation biofuels in order to predict the future viability of the industry in different types of countries. Based on the findings of this paper, the empirical evidence and quantitative analysis broadly agree. Biofuels are, and will remain, a viable fuel source over the next several decades, but only under specific circumstances. Generally speaking, we can summarize our recommendations as the following.

Biofuels are viable in most developed nations, with the focus on advancing production of 2G biofuels. Developed nations fall into two categories, those with previously established 1G biofuel infrastructure and those without it. If a nation has previously established 1G biofuel infrastructure, production should continue and increased production is possible. However, they, as well as those without previous infrastructure, should focus future investment on 2G biofuels due to their greater sustainability, long-term profitability, and smaller environmental impact. While it will take time to build up 2G infrastructure, it will earn back the investment once established. However, 1G biofuels are expected to be produced at roughly similar levels until 2040. If 2G biofuel production increases faster than expected and surpasses that of 1G biofuels, 1G biofuels could and should be phased out slowly in favor of 2G biofuels.

Unlike developed nations, developing nations lack the existing wealth to make the same type of investments viable. Developing nations should not pursue 2G biofuels, at least those types we investigated here. The expensive research and development push them out of practical reach. However, they can pursue 1G biofuel production with strong investment and public support if the nation is favorably predisposed to their production provided that they possess ample arable land and water resources. If, however, they possess a competitive advantage in another alternative fuel with lower emissions or can import an alternative fuel cheaply, they should avoid significant investment in 1G biofuels, regardless of favorable predisposition. In these cases, the expense of the infrastructure, the emissions, and the impact on the food supply are not worth the investment. Exceptions to the rule include Brazil, a country that has the necessary infrastructure, public-private support, and demand, as evidenced by our empirical findings, to manufacture 1G and 2G biofuels. Developing countries that have similar established biofuels industries and networks can pursue investments in these kinds of alternative fuels.

Furthermore, any nation that wishes to pursue 1G biofuels must do so without the intent to make them the predominant fuel source in the country because of the large scale of required agricultural cultivation. To do so
would dramatically decrease a country’s agricultural export potential and possibly endanger its food supply, not to mention cause adverse environmental effects. 2G biofuels, which are produced from non-food crops, could potentially meet total fuel demand, but at the moment there is no large-scale commercial production of 2G biofuels. Also, depending on the type of feedstock, cost of feedstock and conversion, cellulosic biofuels are up to three times more expensive than energy equivalent gasoline. As a result, any future production would require large scale investment and policy considerations. Any nation wishing to develop 2G biofuels should do so with caution due to the recognition of the difficulty and possibility of extended costs with such developments. Careful consideration of the role second-generation biofuels would play in long-term energy goals, in particular the 2007 Energy Independence and Security Act (Renewable Fuel Standard), would also be required.

6.1 Aggregate Results
6.1.1 Tabulation of Findings:

<table>
<thead>
<tr>
<th>Description (CASE)</th>
<th>Developed Nation (2G) CASE A</th>
<th>Developing Nation (2G) CASE B</th>
<th>Developed Nation (1G) CASE C</th>
<th>Developing Nation (1G) CASE D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Profit</td>
<td>209,313.53</td>
<td>-1,176,017.59</td>
<td>166,952.10</td>
<td>-91,300.00</td>
</tr>
<tr>
<td>Net Present Value</td>
<td>100,690.19</td>
<td>-1,011,217.59</td>
<td>40,982.74</td>
<td>39,224.68</td>
</tr>
<tr>
<td>Return on Investment</td>
<td>1.41</td>
<td>0.32</td>
<td>1.17</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Case A has the highest NPV and Operating Profit amounts out of all the Cases that were modelled. A developed nation, with the right amount of investment and the relatively low input costs to produce 2G biofuels, can capitalize on the earning potential of 2G biofuels, specifically miscanthus-based cellulosic ethanol. In this case, developed nation plants with well-developed and optimized 2G biofuels plants stand to earn substantial profits.

When choosing between Case A (2G) or Case C (1G) biofuels plant operation for developed nations, Case A 2G biofuels has the highest NPV and should be the primary choice over Case C. We expect this result to hold, especially in the near future when 2G biofuels production becomes more efficient and realizes its cost-savings in inputs as compared to 1G biofuels. While the current capital, chemical, and maintenance costs for 2G biofuels plants are above that of 1G, feedstock costs tend to be lower and projected revenues are higher. Assuming input prices stay the same and innovation and R&D on 2G biofuels leads to lower capital and conversion costs, 2G biofuels could be considered a “cash cow” for developed countries that generates a growing stream of profits.

Case B, or developing nation (2G) plant, should not continue because of a negative NPV value. This value would mean that the project will experience negative returns over its lifetime. 2G biofuels do require a large investment initially and revenues need to help cover the cost. However, for most developing nations, the costs can be high due to corruption/waste or inexperience handling the technology and production processes; furthermore, export or domestic markets can be difficult to find or penetrate, given the high relative costs to businesses in developing countries to convert their machinery towards biofuels.

For Case D, we find that while the NPV is positive, indicating that we should push through with the investment, the operating profit is actually negative. Thus, the NPV calculation is deceptive as the project is kept alive by FDI or by financing from investments. The investment in 1G in most developing nations can proceed, but would require some significant public-private investments for the plant and operation survive and produce. Most developing nations are familiar with the production of 1G biofuels, although investment costs may require external support.

An ROI greater than one indicates that the revenue stream outweighs the production or operating costs by a certain margin. Clearly, Case A has the highest ROI of the four cases, due to the high potential revenue and less expenses of 2G biofuels, as opposed to Case C 1G biofuels for developed countries. Case B 2G for developing countries. Although Case D has a positive NPV value, its return to investment is very low and is less than 1, suggesting that in the long-run, 1G biofuels production in a developing country may be unsustainable and unprofitable.
The model findings agree with the empirical evidences presented in Section 4. Although the future of biofuels seems secure for most developed countries like the US and developing countries with already robust biofuel industries, such as Brazil, the use of biofuels as a mainstream fuel outside these types of countries is unlikely.

6.1.2 Country-Industry Profitability and Revenue Comparisons

<table>
<thead>
<tr>
<th>Description (CASE) – in thousands of $</th>
<th>Developed Nation (2G) CASE A</th>
<th>Developed Nation (2G) CASE B</th>
<th>Developed Nation (1G) CASE C</th>
<th>Developed Nation (1G) CASE D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue per Gallon</td>
<td>13.61</td>
<td>10.25</td>
<td>11.26</td>
<td>4.59</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (USA)</td>
<td>188,495,651.54</td>
<td>-</td>
<td>156,017,625.99</td>
<td>-</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (Germany)</td>
<td>10,216,577.94</td>
<td>-</td>
<td>8,456,249.38</td>
<td>-</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (Brazil)</td>
<td>-</td>
<td>51,626,852.05</td>
<td>-</td>
<td>23,113,219.12</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (Southeast Asia/Thailand/Indonesia)</td>
<td>-</td>
<td>2,368,863.77</td>
<td>-</td>
<td>1,060,534.69</td>
</tr>
<tr>
<td>Profit per Gallon</td>
<td>3.95</td>
<td>-</td>
<td>3.15</td>
<td>-</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (US)</td>
<td>54,715,400.00</td>
<td>-</td>
<td>43,633,800.00</td>
<td>-</td>
</tr>
<tr>
<td>Expand to National Scale Annual Revenue (Germany)</td>
<td>2,965,607.66</td>
<td>-</td>
<td>2,364,978.26</td>
<td>-</td>
</tr>
<tr>
<td>Biofuels Production Capacity per Year (in thousands of Gallons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>13,852,000.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>750,786.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>5,036,571.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South East Asian (Thailand/Indonesia)</td>
<td>231,099.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CASE Table 2: NSAR Revenue and Profit per Gallon Values

Revenue per gallon and profit per gallon were calculated by dividing revenues and operating profits of each case, respectively, by the 52,930,105.2 gallons of biofuels produced by our 50,000 hectare plant. We then multiplied the results by the annual biofuels production capacity\(^36\) to get the National Scale Annual Revenue (NSAR). No attempt was made to get the NSAR value for Case B and D given that there are negative operating profits.

We calculate the expansion of our model revenue and operating profit result to a national scale for developed countries USA and Germany (EU). Similarly, we calculated the values for developing countries Brazil and Thailand/Indonesia, the latter both having similar production capacities.

6.1.3 Summary of Recommendations

From the table, we see that 2G biofuels are generally more profitable than 1G biofuels, although developing country 2G biofuel revenues per gallon lag behind that of developed countries. It is possible that the lack of a strong export market, which is a reality for most developing nations, and lower domestic demand drops the revenue of a developing nation’s biofuel yield per gallon. The lower demand could result from less emphasis on biofuel policy or from the costs of converting machinery to accept biofuels. These developing nations may

have to lower the price of their biofuels to entice buyers from relatively cheaper gasoline substitutes, leading to smaller revenues and negative profits in the long run.

Revenues from developing countries for 1G and 2G biofuels can be quite substantial though the profit per barrel is negative due to the high-relative cost and inadequate revenue generation to offset these costs. Revenue generation for 2G biofuels is much higher than that of 1G biofuels, suggesting that 2G biofuels could be a lucrative investment for most developing countries in the future, as technology and domestic operations become more inexpensive. For most developing nations, the cost of producing 1G biofuels is cheaper and the biofuels industry is more familiar with the technology to produce these kinds of biofuels.

The US, with the highest production capacity for biofuels nets the largest NSAR value based on revenues per gallon, while Brazil has the next highest value. Profits per gallon are still generally higher for developed nation 2G biofuels as opposed to 1G biofuels, as reflected in the higher revenue amount for 2G biofuels.

The US and Germany are capable of producing both kinds of biofuels at a profitable rate; however, capacity and total land allocation will ultimately decide the potential of a developed country to produce biofuels.

6.2 Comparing Gasoline and Agriculture Production in the US

We compare our NSAR values to that of Gasoline/Oil and Agricultural production in the US.

The US domestic production of oil is around 2,374,537,000 barrels annually. We multiply this amount by the price of oil, at $100 dollars a barrel, to get $237,453,700,000 or $237.454 billion of oil revenue. Clearly, biofuels cannot compare to the raw revenue generation of crude oil in the US. Despite this, 2G biofuels produced at a national scale has the potential to surpass the revenues of oil in the future. Experts from Bloomberg New Energy Finance estimate that by 2030, the advanced biofuels industry will create jobs, and spur economic growth and energy security. For developed countries like the US, advanced biofuels would help create 1.37 million jobs while displacing close to 16% of gasoline consumption. Projected revenue from 2G biofuels in 2030 is expected to be $663 billion. For larger developing countries, 2G biofuels also has strong payoffs by 2030. Brazil could create 1.25 million jobs and achieve 2G revenue of $662 billion, while India could create 910,000 jobs and gain 2G revenue of $329 billion, with an additional 1.057 billion gallons available for export.

For the agricultural industry, the opportunity cost of a biofuels plant is the loss of profits from agriculture production because of the land allocation to accommodate the former.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Harvested Area (million acres)</th>
<th>Cash Receipts from Sales ($ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (grain)</td>
<td>84</td>
<td>63.9</td>
</tr>
<tr>
<td>Soybeans</td>
<td>73.8</td>
<td>37.6</td>
</tr>
<tr>
<td>Hay</td>
<td>55.7</td>
<td>6.7</td>
</tr>
<tr>
<td>Wheat</td>
<td>45.7</td>
<td>14.6</td>
</tr>
<tr>
<td>Cotton</td>
<td>9.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Sorghum (grain)</td>
<td>3.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Rice</td>
<td>2.6</td>
<td>2.9</td>
</tr>
</tbody>
</table>


In this US Department of Agriculture (USDA) production table, the US agricultural industry contributes $143 billion a year to the economy, with corn or grain as the main cash crop at $63.9 billion. The opportunity cost of agriculture, then, is less than if we were to pursue a biofuels, and biofuels plants will surpass the agricultural revenues due to the relatively high cost of energy and the higher price biofuels commands. US 1G and 2G biofuels are expected to earn $188.496 billion and $156.018 billion, respectively, making the biofuels

industry a better investment than the agricultural industry. However, one must still consider the trade-off between domestic food production and biofuels production, as the latter can reduce food supply, increase US reliance on food imports, and increase the price of certain staple comestibles. It is also possible that the cost of converting land to biofuels and overall production costs make profit margins from biofuels smaller though revenue contributions to US economy are larger.

For developing countries, the agricultural industry remains the better investment. Though developing countries like Brazil can experience higher revenues from biofuels than their agricultural sectors, the cost of operating biofuels plants is high and can result in unprofitability. The value of Brazilian agriculture crops is at 108 billion Brazil reais or 45.90 billion U.S. dollars\(^{41}\). For Brazil, the 1G revenue is lower than this amount, but the 2G revenue is much higher; the Brazilian biofuels industry has been growing, however, and can potentially reverse any negative returns in the future once technology and processing become more efficient.

For other developing countries, such as Southeast Asian countries, which are still building up their potential for biofuels production, the revenues generated from biofuels are uncompetitive and costs are too high to sustain a large, profitable biofuels operation. Our model calculation shows that biofuels revenue is very small and that there is no significant difference between 1G or 2G biofuels at national scales. Profits per gallon are also negative.

Total sales of Philippine agriculture (farming sector) amounted to 1.5 trillion Philippine pesos, or $33.68 billion U.S. dollars\(^{42}\), a number much greater than revenues from either biofuel type. These nations will benefit from reserving and preserving land for increased agricultural production. In general, Southeast Asian biofuels returns pale in comparison to their more developed, tested, and competitive agriculture sectors that already have historically strong export and domestic markets. This finding may also apply to similar, smaller developing economies.

6.3 The Effect of Corruption

Corruption, a waste cost which is accounted for in \(\varepsilon_n\), approaches close to $700 million annually for most developing countries well endowed with natural land resources, according to Transparency International. Corruption costs are mostly cash outflows due to land acquisition and registration issues, as well as fixed administration payoffs over the lifetime of the project\(^{43}\).

Corruption cost per hectare in this model was calculated by $700,000,000 annual corruption in the land, natural resources sector divided by 50,000,000 total hectares of baseline arable land in most developing countries, then multiplied by 50,000 biofuel model plant hectares to equal $700,000 corruption costs per plant\(^{44}\). Corruption in developing countries can take many forms, including payoffs to government contractors and various offices to obtain permits or licenses to operate.

In developed countries, corruption is lower due to more stringent environmental protection mechanisms, transparency, and disincentives for the public sector to engage in corrupt means. We estimate that for developed countries, the corruption level would average 10% of that of developing countries, or $70 million annually. We find that corruption in developed countries revolve around subsidies/compliance and trading fraud, where US biofuels producers pocketed upwards of $70 million from trading fraudulent credits with every gallon of fuel produced\(^{45}\).

Corruption cost per hectare in this model was calculated by $70,000,000 annual corruption in the land, natural resources sector divided by 134,000,000 total hectares of baseline arable land in most developed countries (US), then multiplied by 50,000 biofuel model plant hectares equals $26,119.40 corruption costs per plant\(^{46}\). Clearly, the corruption cost per plant would be lower, as corruption in most developed countries is not very extensive.

\(^{41}\)Cremaq, P. *The Miracle of the Cerrado*. August 26, 2010

\(^{42}\)Valencia C. *Agri sector posts 1.5% growth*. January 23, 2014


\(^{44}\)Langeveld JWA, Dixon J, van Keulen H, QuistWessel PMF. *Analyzing the effect of biofuel expansion on land use in major producing countries: evidence of increased multiple cropping*. 2014

\(^{45}\)Dempsey, M. *Inhofe Requests Hearing on ‘RINGate’*. 2012

\(^{46}\)Langeveld JWA, Dixon J, van Keulen H, QuistWessel PMF. *Analyzing the effect of biofuel expansion on land use in major producing countries: evidence of increased multiple cropping*. 2014
Corruption costs may significantly hurt a developing nation’s ability to not only reduce already high costs to produce and develop biofuels, but also to attract foreign investors to fund the project. In the overall calculation in the model, funds lost to corruption are quite small and are unlikely to significantly contribute to the costs of an already expensive developing country biofuels operation (per plant basis).

While significant R&D investments from FDI and domestic funding can outweigh some of the corruption costs inherent in developing countries, smaller developing states like Tanzania experience limited funding possibilities and governance problems that hinder large investments from foreign companies\(^ {47}\). Biofuels operations can fail in the planning stages or be very unlikely in these cases.

6.4 Effect of Subsidies

Now, we will account for the effect of subsidies on biofuels in our equation. Subsidies are counted as funds from financing, and would be added to the total Net Cash Inflow.

Biofuel support in the US and in most developed countries, such as Australia, is very strong and biofuel producers receive a significant subsidy of from government institutions. An increase in total transfers towards in support of biofuels can be observed in developed countries, as renewable energy rises to the forefront of policy. Approximately $20 billion was disbursed yearly as subsidies for biofuel production and consumption in the US and in various G-20 countries\(^ {48} \) \(^ {49}\). In contrast, biofuel subsidies for developing countries, such as Indonesia and China, only number close to $200 million annually\(^ {50}\).

We factor the effect of cash subsidies to our model, as a cash subsidy account similar to “funds from financing” in our NPV calculation. The subsidy per hectare is approximately $62 to give us $3,100,000 for 50,000 hectares\(^ {51}\). From observation, this amount ($3,100 in thousands), will not result in any major change in our original calculations; for instance, Case B will still have a negative NPV value. This result suggests that the effect of subsidies may be small in the overall profitability calculation.

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\(^ {48}\) Ivetta Gerasimchuk RB, Christopher Beaton, Chris Charles. State of Play on Biofuel Subsidies: Are policies ready to shift? 2012


\(^ {50}\) Quirke, D. et. al. Biofuels: At what cost? Government Support for Ethanol and Biodiesel in Australia. 2008


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